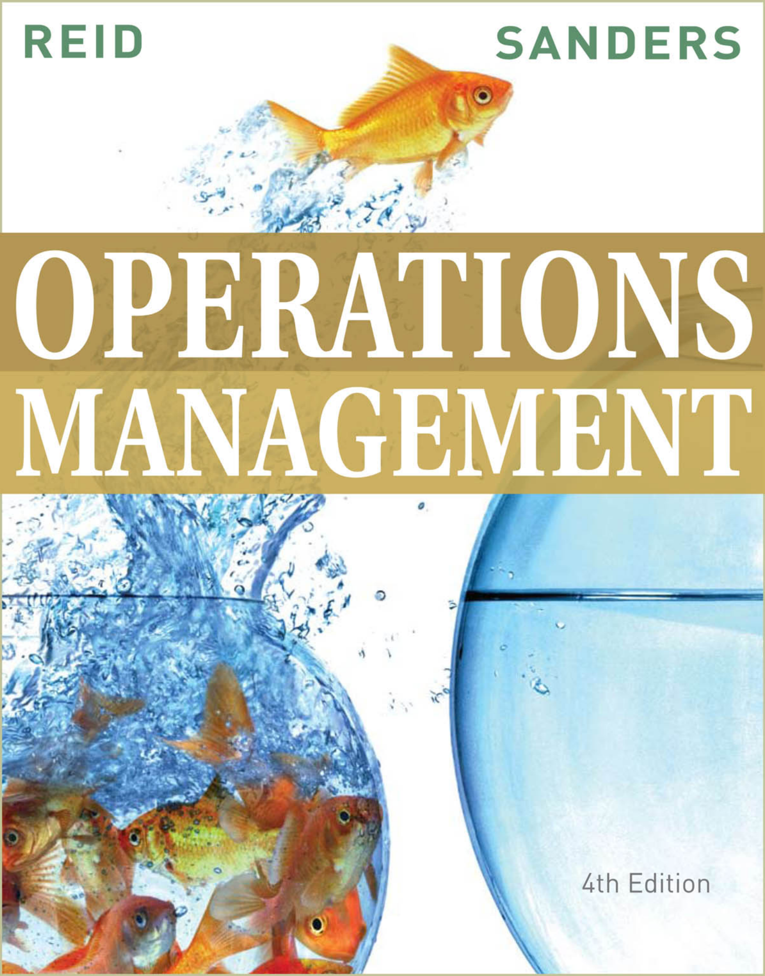
REID SANDERS

OPERATIONS MANAGEMENT



4th Edition

Contents

Operations Management

An Integrated Approach

CHAPTER 1

Introduction to Operations Management

LEARNING OBJECTIVES

After completing this chapter you should be able to

1. Define operations management.
2. Explain the role of operations management in business.
3. Describe decisions that operations managers make.
4. Describe the differences between service and manufacturing operations.
5. Identify major historical developments in operations management.
6. Identify current trends in operations management.
7. Describe the flow of information between operations management and other business functions.

CHAPTER OUTLINE

WHAT'S IN OM FOR ME?

ACC FIN MKT OM HRM MIS

LWA/Larry Williams/Getty Images, Inc.

Many of you reading this book may think that you don't know what operations management (OM) is or that it is not something you are interested in. However, after reading this chapter you will realize that you already know quite a bit about operations management. You may even be working in an operations management capacity and have used certain operations management techniques. You will also realize that operations management is probably the most critical business function today. If you want to be on the frontier of business competition, you want to be in operations management.

Today companies are competing in a very different environment than they were only a few years ago. To survive, they must focus on quality, time-based competition, efficiency, international perspectives, and customer relationships. Global competition, e-business, the Internet, and advances in technology require flexibility and responsiveness. Increased financial pressures require lean and agile organizations that are free of waste. This new focus has placed operations management in the business limelight because it is the function through which companies can achieve this type of competitiveness.

Consider some of today's most successful companies, such as Wal-Mart, Southwest Airlines, General Electric, Starbucks, Apple Computer, Toyota, FedEx, and Procter & Gamble. These companies have achieved world-class status in large part due to a strong focus on operations management. In this book you will learn specific tools and techniques of operations management that have helped these and other companies achieve their success.

The purpose of this book is to help prepare you to be successful in this new business environment. Operations management will give you an understanding of how to help your organization gain a competitive advantage in the marketplace. Regardless of whether your area of expertise is marketing, finance, MIS, or operations, the techniques and concepts in this book will help you in your business career. The material will teach you how your company can offer goods and services cheaper, better, and faster. You will also learn that operations management concepts are far-reaching, affecting every aspect of the organization and even everyday life.

WHAT IS OPERATIONS MANAGEMENT?

Every business is managed through three major functions: finance, marketing, and operations management. Figure 1-1 illustrates this by showing that the vice presidents of each of these functions report directly to the president or CEO of the company. Other business functions—such as accounting, purchasing, human resources, and engineering—support these three major functions. Finance is the function responsible

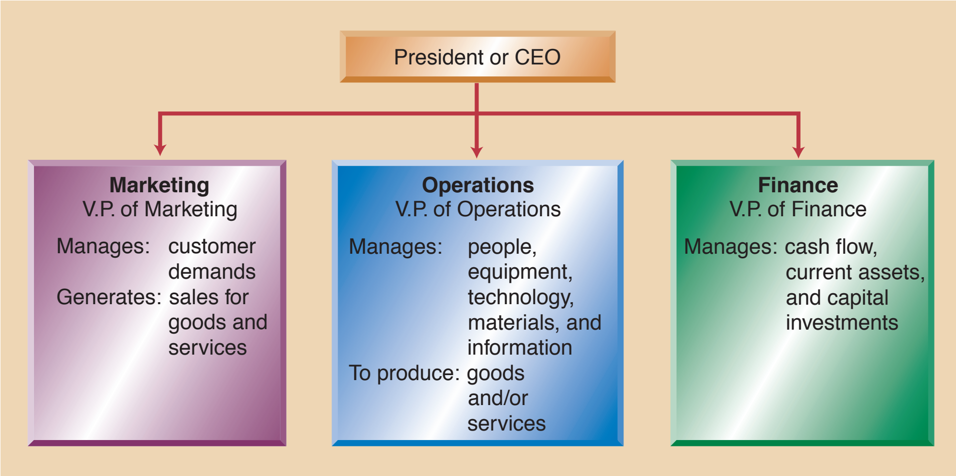


FIGURE 1-1

Organizational chart showing the three major business functions

for managing cash flow, current assets, and capital investments. Marketing is responsible for sales, generating customer demand, and understanding customer wants and needs. Most of us have some idea of what finance and marketing are about, but what does operations management do?

Operations management (**OM**) is the business function that plans, organizes, coordinates, and controls the resources needed to produce a company's goods and services. Operations management is a *management* function. It involves managing people, equipment, technology, information, and many other resources. Operations management is the central core function of every company. This is true whether the company is large or small, provides a physical good or a service, is for-profit or not-for-profit. Every company has an operations management function. Actually, all the other organizational functions are there primarily to support the operations function. Without operations, there would be no goods or services to sell. Consider a retailer such as The Gap, which sells casual apparel. The marketing function provides promotions for the merchandise, and the finance function provides the needed capital. It is the operations function, however, that plans and coordinates all the resources needed to design, produce, and deliver the merchandise to the various retail locations. Without operations, there would be no goods or services to sell to customers.

▶ **Operations management (OM)**
The business function responsible for planning, coordinating, and controlling the resources needed to produce a company's goods and services.

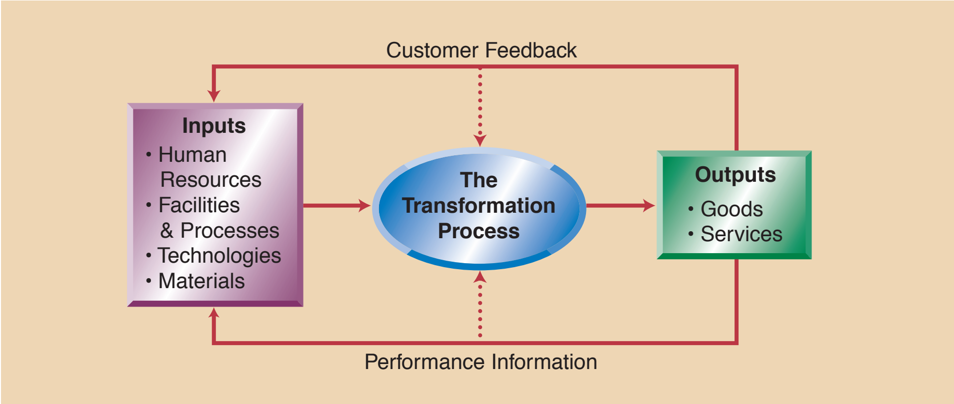
The **role of operations management** is to transform a company's inputs into the finished goods or services. Inputs include human resources (such as workers and managers), facilities and processes (such as buildings and equipment), as well as materials, technology, and information. Outputs are the goods and services a company produces. Figure 1-2 shows this *transformation process*. At a factory the transformation is the physical change of raw materials into products, such as transforming leather and rubber into sneakers, denim into jeans, or plastic into toys. At an airline it is the efficient movement of passengers and their luggage from one location to another. At a hospital it is organizing resources such as doctors, medical procedures, and medications to transform sick people into healthy ones.

▶ **Role of operations management**
To transform organizational inputs into outputs

Operations management is responsible for orchestrating all the resources needed to produce the final product. This includes designing the product; deciding what resources are needed; arranging schedules, equipment, and facilities; managing inventory; controlling quality; designing the jobs to make the product; and designing work methods. Basically, operations management is responsible for all aspects of the process of transforming inputs into outputs. Customer feedback and performance

FIGURE 1-2

The transformation process



information are used to continually adjust the inputs, the transformation process, and characteristics of the outputs. As shown in Figure 1-2, this transformation process is dynamic in order to adapt to changes in the environment.

Proper management of the operations function has led to success for many companies. For example, in 1994 Dell Computer Corporation was a second-rate computer maker that managed its operations similarly to others in the industry. Then Dell implemented a new business model that completely changed the role of its operations function. Dell developed new and innovative ways of managing the operations function that have become one of today's best practices. These changes enabled Dell to provide rapid product delivery of customized products to customers at a lower cost. Today Dell customized computers can be en route to the customer within 36 hours, at a price 10–15 percent lower than industry standard. Dell's model is one many have tried to emulate and is the key to its being an industry leader.

Just as proper management of operations can lead to company success, improper management of operations can lead to failure. This is illustrated by Kozmo.com, a Web-based home delivery company founded in 1997. Kozmo's mission was to deliver products to customers—everything from the latest video to ice cream—in less than an hour. Kozmo was technology enabled and rapidly became a huge success. However, the initial success gave rise to overly fast expansion. The company found it difficult to manage the operations needed in order to deliver the promises made on its Web site. The consequences were too much inventory, poor deliveries, and losses in profits. The company rapidly tried to change its operations, but it was too late. It had to cease operations in April 2001.

LINKS TO PRACTICE

The E-tailers
www.Amazon.com
www.Barnesandnoble.com

© Scott Sady/AP/Wide World Photos

The Web-based age has created a highly competitive world of on-line shopping that poses special challenges for operations management. The Web can be used for on-line purchasing of everything from CDs, books, and groceries to prescription medications and automobiles. The Internet has given consumers flexibility; it has also created one of the biggest challenges for companies: deliver-

ing exactly what the customer ordered at the time promised. As we saw with the example of Kozmo.com, making promises on a Web site is one thing; delivering on those promises is yet another. Ensuring that orders are delivered from "mouse to house" is the job of operations and is much more complicated than it might seem. In the 1990s many dot-com companies discovered just how difficult this is. They were not able to generate a profit and went out of business. To ensure meeting promises, companies must forecast what customers want and maintain adequate inventories of goods, manage distribution centers and warehouses, operate fleets of trucks, and schedule deliveries while keeping costs low and customers satisfied. Many companies like Amazon.com manage almost all aspects of their operation. Other companies hire outside firms for certain functions, such as outsourcing the management of inventories and deliveries to UPS. Competition among e-tailers has become intense as customers demand increasingly shorter delivery times and highly customized products. Same-day service has become common in metropolitan areas. For example, Barnesandnoble.com provides same-day delivery in Manhattan, Los Angeles, and San Francisco. Understanding and managing the operations function of an on-line business has become essential in order to remain competitive.

For operations management to be successful, it must add value during the transformation process. We use the term **value added** to describe the net increase between the final value of a product and the value of all the inputs. The greater the value added, the more productive a business is. An obvious way to add value is to reduce the cost of activities in the transformation process. Activities that do not add value are considered a waste; these include certain jobs, equipment, and processes. In addition to value added, operations must be efficient. **Efficiency** means being able to perform activities well and at the lowest possible cost. An important role of operations is to analyze all activities, eliminate those that do not add value, and restructure processes and jobs to achieve greater efficiency. Because today's business environment is more competitive than ever, the role of operations management has become the focal point of efforts to increase competitiveness by improving value added and efficiency.

▶ **Value added**
The net increase created during the transformation of inputs into final outputs.

▶ **Efficiency**
Performing activities at the lowest possible cost.

DIFFERENCES BETWEEN MANUFACTURING AND SERVICE ORGANIZATIONS

Organizations can be divided into two broad categories: **manufacturing organizations** and **service organizations**, each posing unique challenges for the operations function. There are two primary distinctions between these categories. First, manufacturing organizations produce physical, tangible goods that can be stored in inventory before they are needed. By contrast, service organizations produce intangible products that cannot be produced ahead of time. Second, in manufacturing organizations most customers have no direct contact with the operation. Customer contact occurs through distributors and retailers. For example, a customer buying a car at a car dealership never comes into contact with the automobile factory. However, in service organizations the customers are typically present during the creation of the service. Hospitals, colleges, theaters, and barber shops are examples of service organizations in which the customer is present during the creation of the service.

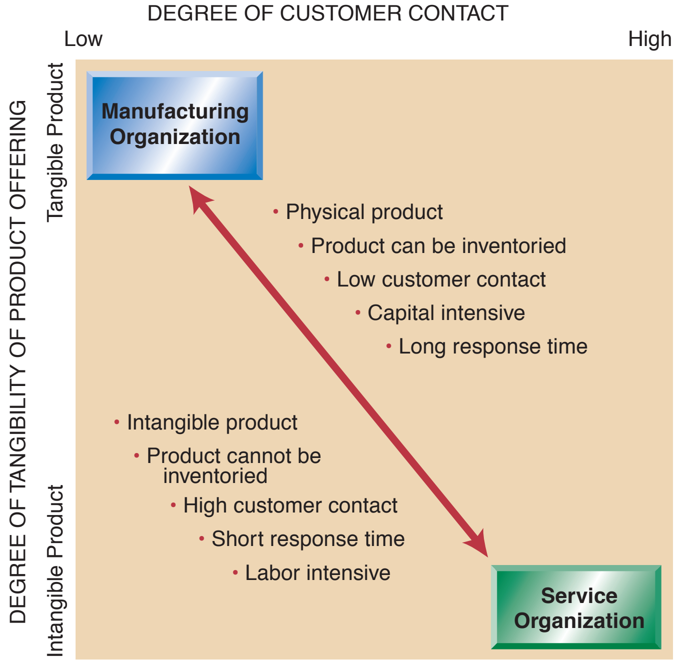
▶ **Manufacturing organizations**
Organizations that primarily produce a tangible product and typically have low customer contact.

▶ **Service organizations**
Organizations that primarily produce an intangible product, such as ideas, assistance, or information, and typically have high customer contact.

The differences between manufacturing and service organizations are not as clear-cut as they might appear, and there is much overlap between them. Most manufacturers provide services as part of their business, and many service firms manufacture physical goods that they deliver to their customers or consume during service delivery. For example, a manufacturer of furniture may also provide shipment of goods and assembly of furniture. A barber shop may sell its own line of hair care

FIGURE 1-3

Characteristics of manufacturing and service organizations



products. You might not know that General Motors' greatest return on capital does not come from selling cars, but rather from postsales parts and service. Figure 1-3 shows the differences between manufacturing and services, focusing on the dimensions of product tangibility and the degree of customer contact. It shows the extremes of pure manufacturing and pure service, as well as the overlap between them.

Even in pure service companies some segments of the operation may have low customer contact while others have high customer contact. The former can be thought of as "back room" or "behind the scenes" segments. Think of a fast-food operation such as Wendy's, for which customer service and customer contact are important parts of the business. However, the kitchen segment of Wendy's operation has no direct customer contact and can be managed like a manufacturing operation. Similarly, a hospital is a high-contact service operation, but the patient is not present in certain segments, such as the lab where specimen analysis is done.

In addition to pure manufacturing and pure service, there are companies that have some characteristics of each type of organization. It is difficult to tell whether these companies are actually manufacturing or service organizations. Think of a post office, an automated warehouse, or a mail-order catalog business. They have low customer contact and are capital intensive, yet they provide a service. We call these companies *quasi-manufacturing organizations.*

LINKS TO PRACTICE

U.S. Postal Service
www.usps.com

Justin Sullivan/Getty Images, Inc.

The U.S. Postal Service is an example of a quasi-manufacturing type of company. It provides a service: speedy, reliable delivery of letters, documents, and packages. Its output is intangible and cannot be stored in inventory. Yet most operations management decisions made at the Postal Service are similar to those that occur in manufacturing. Customer contact is low, and at any one time there

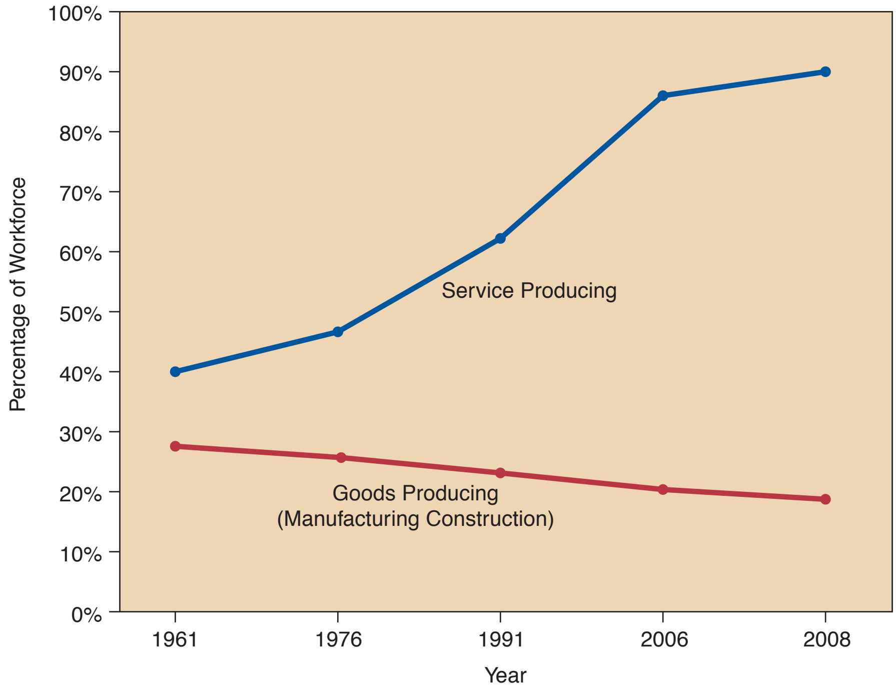


FIGURE 1-4

U.S. employment by economic sector

is a large amount of inventory. The Postal Service is capital intensive, having its own facilities and fleet of trucks and relying on scanners to sort packages and track customer orders. Scheduling enough workers at peak processing times is a major concern, as is planning delivery schedules. Note that although the output of the U.S. Postal Service is a service, inputs include labor, technology, and equipment. The responsibility of OM is to manage the conversion of these inputs into the desired outputs. Proper management of the OM function is critical to the success of the U.S. Postal Service.

It is important to understand how to manage both service and manufacturing operations. However, managing service operations is of especially high importance. The reason is that the service sector constitutes a dominant segment of our economy. Since the 1960s, the percentage of jobs in the service-producing industries of the U.S. economy has increased from less than 50 to over 80 percent of total nonfarm jobs. The remaining 20 percent are in the manufacturing and goods-producing industries. Figure 1-4 illustrates this large growth of the service sector.

OPERATIONS MANAGEMENT DECISIONS

In this section we look at some of the specific decisions that operations managers have to make. The best way to do this is to think about decisions we would need to make if we started our own company—say, a company called Gourmet Wafers that produces praline–pecan cookies from an old family recipe. Think about the decisions that would have to be made to go from the initial idea to actual production of the product: that is operations management. Table 1-1 breaks these down into the generic decisions that would be appropriate for almost any good or service, the specific decisions required for our example, and the formal terms for these decisions that are used in operations management.

TABLE 1-1

Operations Management Decisions for Gourmet Wafers

General Decisions to Be Made	Decisions Specific for Cookie Production	Operations Management Term
What are the unique features of the business that will make it competitive?	The business offers freshly baked cookies "homemade" style, in a fast-food format.	Operations strategy
What are the unique features of the product?	The unique feature of the cookies is that they are loaded with extra-large and crunchy pecans and are fresh and moist.	Product design
What are the unique features of the process that give the product its unique characteristics?	A special convection oven is used to make the cookies in order to keep them fresh and moist. The dough is allowed to rise longer than usual to make the cookies extra light.	Process selection
What sources of supply should we use to ensure regular and timely receipt of the exact materials we need? How do we manage these sources of supply?	The key ingredients, pecans and syrup, will be purchased from only one supplier located in South Carolina because it offers the best products. A relationship is worked out in which the supplier sends the ingredients on the exact schedule that they are needed.	Supply chain management
How will managers ensure the quality of the product, measure quality, and identify quality problems?	A quality check is made at each stage of cookie production. The dough is checked for texture; the pecans are checked for size and freshness; the syrup is checked for consistency.	Quality management
What is the expected demand for the product?	Expected sales for each day of the week have been determined; for example, it is expected that more cookies will be sold on weekdays and most during the lunch hour. Expected cookie sales for each month and for the year have also been determined.	Forecasting
Where will the facility be located?	After looking at locations of customers and location costs, it is decided that the facility will be located in a shopping mall.	Location analysis
How large should the facility be?	The business needs to be able to produce 200 cookies per hour, or up to 2000 cookies per day.	Capacity planning
How should the facility be laid out? Where should the kitchen and ovens be located? Should there be seating for customers?	Decisions are made about where the kitchen will be located and how the working area will be arranged for maximum efficiency. The business is competing on the basis of *speed* and *quality;* therefore, the facility should be arranged to promote these features. There will be a small seating area for customers and a large counter and display case for buying.	Facility layout
What jobs will be needed in the facility, who should do what task, and how will their performance be measured?	Two people will be needed in the kitchen during busy periods and one during slow periods. Their job duties are determined. One person will be needed for order taking at all times.	Job design and work measurement
How will the inventory of raw materials be monitored? When will orders be placed, and how much will be kept in stock?	A different policy is developed for common ingredients, such as flour and sugar. These ingredients will be ordered every two weeks for a two-week supply. A special purchasing arrangement is worked out with the supplier of specialty ingredients.	Inventory management
Who will work on what schedule?	Two people will work the counter in split shifts. One kitchen employee will work a full shift, with a second employee working part-time.	Scheduling

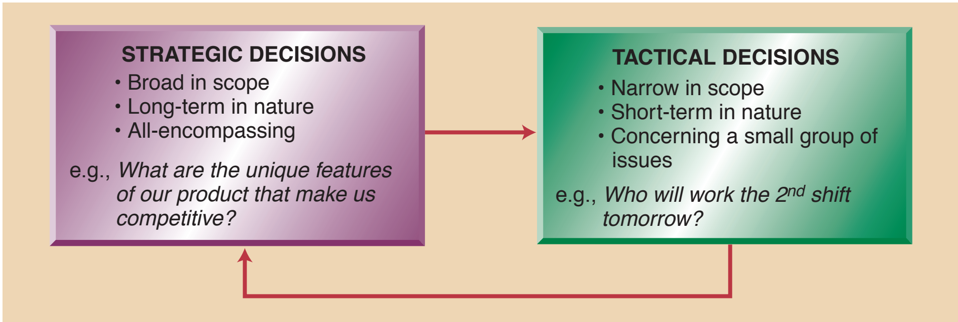


FIGURE 1-5

The relationship between strategic and tactical decisions

Note in the Gourmet Wafers example that the first decisions made were very broad in scope (e.g., the unique features of our product). We needed to do this before we could focus on more specific decisions (e.g., worker schedules). Although our example is simple, this decision-making process is followed by every company, including IBM, General Motors, Lands' End, and your local floral shop. Also note in our example that before we can think about specific day-to-day decisions, we need to make decisions for the whole company that are long-term in nature. Long-term decisions that set the direction for the entire organization are called **strategic decisions**. They are broad in scope and set the tone for other, more specific decisions. They address questions such as: What are the unique features of our product? What market do we plan to compete in? What do we believe will be the demand for our product?

Short-term decisions that focus on specific departments and tasks are called **tactical decisions**. Tactical decisions focus on more specific day-to-day issues, such as the quantities and timing of specific resources. Strategic decisions are made first and determine the direction of tactical decisions, which are made more frequently and routinely. Therefore, we have to start with strategic decisions and then move on to tactical decisions. This relationship is shown in Figure 1-5. Tactical decisions must be aligned with strategic decisions because they are the key to the company's effectiveness in the long run. Tactical decisions provide feedback to strategic decisions, which can be modified accordingly.

▶ **Strategic decisions** Decisions that set the direction for the entire company; they are broad in scope and long-term in nature.

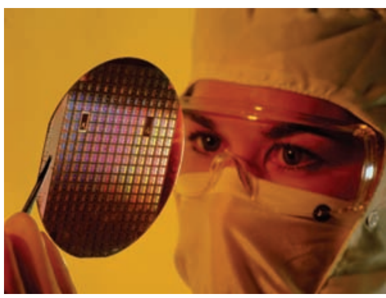
▶ **Tactical decisions** Decisions that are specific and short-term in nature and are bound by strategic decisions.

You can see in the example of Gourmet Wafers how important OM decisions are. They are critical to all types of companies, large and small. In large companies these decisions are more complex because of the size and scope of the organization. Large companies typically produce a greater variety of products, have multiple location sites, and often use domestic and international suppliers. Managing OM decisions and coordinating efforts can be a complicated task, and the OM function is critical to the company's success.

LINKS TO PRACTICE

Texas Instruments Incorporated
www.ti.com

We can illustrate this point by looking at operations management decisions made by Texas Instruments (TI) in order to position itself for global collaboration with customers, distributors, and suppliers. TI realized its business was growing exponentially, with more than 120,000 monthly orders received and processed electronically. The coordination effort encompassed 56 factories, including subcontractors, and the management of over 45,000 products. To succeed, the company needed to develop a system to generate better forecasts, coordinate manufacturing of products, manage orders, and track deliveries. Managing and coordinating global operations management functions was considered paramount to the company's success.



Bruce Ando/Stone/Getty Images, Inc.

TI adopted a comprehensive software package called enterprise resource planning (ERP) that integrates information throughout the organization, manages forecasts, and coordinates factory operations. Designing and implementing the ERP system at TI required an understanding of all the strategic and tactical operations decisions; otherwise, it would not be effective. The system has proven to be a success and a major achievement, enabling TI to consistently manage factory operations across the globe.

PLAN OF THIS BOOK

The purpose here is to provide concepts and techniques that give you the ability to efficiently plan, order, and control the resources needed to produce a company's goods and services. The topics progress from strategic to tactical, similar to the order of decisions used in the Gourmet Wafers example. Figure 1-6 shows the plan of the book. We begin with broad, overarching issues such as product design and process selection. Also early on we cover operations topics that require a strategic perspective and a cultural change within the organization, such as supply chain management, total quality management, and just-in-time systems. We progress to more tactical issues, such as work measurement, inventory management, and scheduling concerns.

We have designed the chapters to provide relevant operations management concepts and techniques that are important to business professionals regardless of their field of study. Throughout the chapters we show how the tools and concepts discussed relate to other functions in the organization and that operations management concepts are far-reaching, affecting every aspect of the organization.

Before You Go On

You should understand that operations management (OM) is the business function responsible for planning, coordinating, and controlling the resources needed to produce a company's goods and services. OM is directly responsible for managing the transformation of a company's inputs (e.g., materials, technology, and information) into finished products and services. OM requires a wide range of strategic and tactical decisions. Strategic decisions are long-range and very broad in scope (e.g., unique features of the company's product and process). They determine the direction of tactical decisions, which are more short term and narrow in scope (e.g., policy for ordering raw materials). All organizations can be separated into manufacturing and service operations, which differ based on product tangibility and degree of customer contact. Service and manufacturing organizations have very different operational requirements.

FIGURE 1-6

Plan of the book

Type of Decision	Operations Management Topic	Chapter
Strategic	Operations Strategy	Ch. 2
	Product Design and Process Selection	Ch. 3
	Supply Chain Management	Ch. 4
	Total Quality Management	Ch. 5 and 6
	Just-in-Time and Lean Systems	Ch. 7
	Forecasting	Ch. 8
	Capacity Planning and Location Analysis	Ch. 9
	Facility Layout	Ch. 10
	Work System Design	Ch. 11
	Inventory and Resource Planning	Ch. 12, 13, and 14
Tactical	Scheduling Issues	Ch. 15 and 16

HISTORICAL DEVELOPMENT

Why OM?

Business did not always recognize the importance of operations management. In fact, following World War II the marketing and finance functions were predominant in American corporations. The United States had just emerged from the war as the undisputed global manufacturing leader due in large part to efficient operations. At the same time, Japan and Europe were in ruins, their businesses and factories destroyed. U.S. companies had these markets to themselves, and so the post-World War II period of the 1950s and 1960s represented the golden era for U.S. business. The primary opportunities were in the areas of marketing, to develop the large potential markets for new products, and in finance, to support the growth. Since there were no significant competitors, the operations function became of secondary importance, because companies could sell what they produced. Even the distinguished economist John Kenneth Galbraith observed, "The production problem has been solved."

Then in the 1970s and 1980s, things changed. American companies experienced large declines in productivity growth, and international competition began to be a challenge in many markets. In some markets such as the auto industry, American corporations were being pushed out. It appeared that U.S. firms had become lax due to the lack of competition in the 1950s and 1960s. They had forgotten about improving their methods and processes. In the meantime, foreign firms were rebuilding their facilities and designing new production methods. By the time foreign firms had recovered, many U.S. firms found themselves unable to compete. To regain their competitiveness, companies turned to operations management, a function they had overlooked and almost forgotten about.

The new focus on operations and competitiveness has been responsible for the recovery of many corporations, and U.S. businesses experienced a resurgence in the 1980s and 1990s. Operations became the core function of organizational competitiveness. Although U.S. firms have rebounded, they are fully aware of continued global competition, scarcity of resources, and increased financial pressure. Companies have learned that to achieve long-run success they must place much importance on their operations.

Historical Milestones

When we think of what operations management does—namely, managing the transformation of inputs into goods and services—we can see that as a function it is as old as time. Think of any great organizational effort, such as organizing the first Olympic games, building the Great Wall of China, or erecting the Egyptian pyramids, and you will see operations management at work. Operations management did not emerge as a formal field of study, however, until the late 1950s and early 1960s, when scholars began to recognize that all production systems face a common set of problems and to stress the systems approach to viewing operations processes.

Many events helped shape operations management. We will describe some of the most significant of these historical milestones and explain their influence on the development of operations management. Later we will look at some current trends in operations management. These historical milestones and current trends are summarized in Table 1-2.

TABLE 1-2

Historical Development of Operations Management

Concept	Time	Explanation
Industrial Revolution	Late 1700s	Brought in innovations that changed production by using machine power instead of human power.
Scientific management	Early 1900s	Brought the concepts of analysis and measurement of the technical aspects of work design and development of moving assembly lines and mass production.
Human relations movement	1930s to 1960s	Focused on understanding human elements of job design, such as worker motivation and job satisfaction.
Management science	1940s to 1960s	Focused on the development of quantitative techniques to solve operations problems.
Computer age	1960s	Enabled processing of large amounts of data and allowed widespread use of quantitative procedures.
Environmental issues	1970s	Considered waste reduction, the need for recycling, and product reuse.
Just-in-time systems (JIT)	1980s	Designed to achieve high-volume production with minimal inventories.
Total quality management (TQM)	1980s	Sought to eliminate causes of production defects.
Reengineering	1980s	Required redesigning a company's processes in order to provide greater efficiency and cost reduction.
Global competition	1980s	Designed operations to compete in the global market.
Flexibility	1990s	Offered customization on a mass scale.
Time-based competition	1990s	Based on time, such as speed of delivery.
Supply chain management	1990s	Focused on reducing the overall cost of the system that manages the flow of materials and information from suppliers to final customers.
Electronic commerce	2000s	Uses the Internet and World Wide Web for conducting business activity.
Outsourcing and flattening of the world	2000s	Convergence of technology has enabled outsourcing of virtually any job imaginable from anywhere around the globe, therefore "flattening" the world.

The Industrial Revolution

► **Industrial Revolution**
An industry movement that changed production by substituting machine power for labor power.

The **Industrial Revolution** had a significant impact on the way goods are produced today. Before this time, products were made by hand by skilled craftspeople in their shops or homes. Each product was unique, painstakingly made by one person. The Industrial Revolution changed all that. It started in the 1770s with the development of a number of inventions that relied on machine power instead of human power. The most important of these was the steam engine, which was invented by James Watt in 1764. The steam engine provided a new source of power that was used to replace human labor in textile mills, machine-making plants, and other facilities. The concept

Courtesy Library of Congress

Steamboat and railroad forging during the Industrial Revolution

Terry Vine/Stone/Getty Images, Inc.

Today's modern work environment

of the factory was emerging. In addition, the steam engine led to advances in transportation, such as railroads, that allowed for a wider distribution of goods.

About the same time, the concept of *division of labor* was introduced. First described by Adam Smith in 1776 in *The Wealth of Nations*, this concept would become one of the important ideas behind the development of the assembly line. Division of labor means that the production of a good is broken down into a series of small, elemental tasks, each of which is performed by a different worker. The repetition of the task allows the worker to become highly specialized in that task. Division of labor allowed higher volumes to be produced, which, coupled with the advances in transportation of steam-powered boats and railroads, opened up distant markets.

A few years later, in 1790, Eli Whitney introduced the concept of *interchangeable parts*. Prior to that time, every part used in a production process was unique. Interchangeable parts are standardized so that every item in a batch of items fits equally. This concept meant that we could move from one-at-a-time production to volume production, for example, in the manufacture of watches, clocks, and similar items.

Scientific Management

▶ **Scientific management** An approach to management that focused on improving output by redesigning jobs and determining acceptable levels of worker output.

Scientific management was an approach to management promoted by Frederick W. Taylor at the turn of the twentieth century. Taylor was an engineer with an eye for efficiency. Through scientific management he sought to increase worker productivity and organizational output. His concept had two key features. First, it assumed that workers are motivated only by money and are limited only by their physical ability. Taylor believed that worker productivity is governed by scientific laws and that it is up to management to discover these laws through measurement, analysis, and observation. Workers are to be paid in direct proportion to how much they produce. The second feature of this approach was the separation of the planning and doing functions in a company, which meant the separation of management and labor. Management is responsible for designing productive systems and determining acceptable worker output. Workers have no input into this process—they are permitted only to work.

Many people did not like the scientific management approach, especially workers, who thought that management used these methods to unfairly increase output without paying them accordingly. Still, many companies adopted the scientific management approach. Today many view scientific management as a major influence in the

field of operations management. For example, *piece-rate incentives*, in which workers are paid in direct proportion to their output, came out of this movement. Also, Taylor introduced a widely used method of work measurement, *stopwatch time studies*. In stopwatch time studies, observations are made and recorded of a worker performing a task over many cycles. This information is then used to set a time standard for performing the particular task. This method is still used today to set a time standard for short, repetitive tasks.

The scientific management approach was popularized by Henry Ford, who used the techniques in his factories. Combining technology with scientific management, Ford introduced the *moving assembly line* to produce Ford cars. Ford also combined scientific management with the division of labor and interchangeable parts to develop the concept of *mass production*. These concepts and innovations helped him increase production and efficiency at his factories.

The Human Relations Movement

▶ **Hawthorne studies**
The studies responsible for creating the human relations movement, which focused on giving more consideration to workers' needs.

The scientific management movement and its philosophy dominated in the early twentieth century. However, this changed with the publication of the results of the **Hawthorne studies**. The purpose of the Hawthorne studies, conducted at a Western Electric plant in Hawthorne, Illinois, in the 1930s, was to study the effects of environmental changes, such as changes in lighting and room temperature, on the productivity of assembly-line workers. The findings from the study were unexpected: the productivity of the workers continued to increase regardless of the environmental changes made. Elton Mayo, a sociologist from Harvard, concluded that the workers were actually motivated by the attention they were given. The idea of workers responding to the attention they are given came to be known as the *Hawthorne effect*.

▶ **Human relations movement**
A philosophy based on the recognition that factors other than money can contribute to worker productivity.

The study of these findings by many sociologists and psychologists led to the **human relations movement**, an entirely new philosophy based on the recognition that factors other than money can contribute to worker productivity. The impact of this new philosophy on the development of operations management has been tremendous. Its influence can be seen in the implementation of a number of concepts that motivate workers by making their jobs more interesting and meaningful. For example, the Hawthorne studies showed that scientific management had made jobs too repetitive and boring. *Job enlargement* is an approach in which workers are given a larger portion of the total task to do. Another approach to giving more meaning to jobs is *job enrichment*, in which workers are given a greater role in planning.

Recent studies have shown that environmental factors in the workplace, such as adequate lighting and ventilation, can have a major impact on productivity. However, this does not contradict the principle that attention from management is a positive factor in motivation.

Management Science

▶ **Management science**
A field of study that focuses on the development of quantitative techniques to solve operations problems.

While some were focusing on the technical aspects of job design and others on the human aspects of operations management, a third approach, called **management science**, was developing that would make its own unique contribution. Management science focused on developing quantitative techniques for solving operations problems. The first mathematical model for inventory management was developed by F. W. Harris in 1913. Shortly thereafter, statistical sampling theory and quality control procedures were developed.

World War II created an even greater need for the ability to quantitatively solve complex problems of logistics control, for weapons system design and deployment of missiles. Consequently, the techniques of management science grew more robust during the war and continued to develop after the war was over. Many quantitative tools emerged to solve problems in forecasting, inventory control, project management, and other areas. A mathematically oriented field, management science provides operations management with tools to assist in decision making. A popular example of such a tool is linear programming.

The Computer Age

In the 1970s the use of computers in business became widespread. With computers, many of the quantitative models developed by management science could be employed on a larger scale. Data processing became easier, with important effects in areas such as forecasting, scheduling, and inventory management. A particularly important computerized system, material requirements planning (MRP), was developed for inventory control and scheduling. Material requirements planning was able to process huge amounts of data in order to compute inventory requirements and develop schedules for the production of thousands of items, processing that was impossible before the age of computers. Today the exponential growth in computing capability continues to impact operations management.

Just-in-Time

Just-in-time (**JIT**) is a major operations management philosophy, developed in Japan in the 1980s, that is designed to achieve high-volume production using minimal amounts of inventory. This is achieved through coordination of the flow of materials so that the right parts arrive at the right place in the right quantity; hence the term *just-in-time*. However, JIT is much more than the coordinated movement of goods. It is an all-inclusive organizational philosophy that employs teams of workers to achieve continuous improvement in processes and organizational efficiency by eliminating all organizational waste. Although JIT was first used in manufacturing, it has been implemented in the service sector, for example, in the food service industry. JIT has had a profound impact on the way companies manage their operations. It is credited with helping turn many companies around and is used by companies such as Honda, Toyota, and General Motors. JIT promises to continue to transform businesses in the future.

▶ **Just-in-time (JIT)**
A philosophy designed to achieve high-volume production through elimination of waste and continuous improvement.

Total Quality Management

As customers demand ever higher quality in their products and services, companies have been forced to focus on improving quality in order to remain competitive. **Total quality management** (**TQM**) is a philosophy—promulgated by "quality gurus" such as W. Edwards Deming—that aggressively seeks to improve product quality by eliminating causes of product defects and making quality an all-encompassing organizational philosophy. With TQM, everyone in the company is responsible for quality. Practiced by some companies in the 1980s, TQM became pervasive in the 1990s and is an area of operations management that no competitive company has been able to ignore. Its importance is demonstrated by the number of companies achieving ISO 9000

▶ **Total quality management (TQM)**
Philosophy that seeks to improve quality by eliminating causes of product defects and by making quality the responsibility of everyone in the organization.

certification. ISO 9000 is a set of quality standards developed for global manufacturers by the International Organization for Standardization (ISO) to control trade into the then-emerging European Economic Community (EEC). Today ISO 9000 is a global set of standards, with many companies requiring their suppliers to meet the standards as a condition for obtaining contracts.

Business Process Reengineering

▶ **Reengineering** Redesigning a company's processes to make them more efficient.

Business process **reengineering** means redesigning a company's processes to increase efficiency, improve quality, and reduce costs. In many companies things are done in a certain way that has been passed down over the years. Often managers say, "Well, we've always done it this way." Reengineering requires asking why things are done in a certain way, questioning assumptions, and then redesigning the processes. Operations management is a key player in a company's reengineering efforts.

Flexibility

▶ **Flexibility** An organizational strategy in which the company attempts to offer a greater variety of product choices to its customers.

▶ **Mass customization** The ability of a firm to highly customize its goods and services at high volumes.

Traditionally, companies competed by either mass-producing a standardized product or offering customized products in small volumes. One of the current competitive challenges for companies is the need to offer to customers a greater variety of product choices of a traditionally standardized product. This is the challenge of **flexibility**. For example, Procter and Gamble offers 13 different product designs in the Pampers line of diapers. Although diapers are a standardized product, the product designs are customized to the different needs of customers, such as the age, sex, and stage of development of the child using the diaper.

One example of flexibility is **mass customization**, which is the ability of a firm to produce highly customized goods and services and to do it at the high volumes of mass production. Mass customization requires designing flexible operations and using delayed product differentiation, also called postponement. This means keeping the product in generic form as long as possible and postponing completion of the product until specific customer preferences are known.

Time-Based Competition

▶ **Time-based competition** An organizational strategy focusing on efforts to develop new products and deliver them to customers *faster* than competitors.

One of the most important trends within companies today is **time-based competition**—developing new products and services faster than the competition, reaching the market first, and meeting customer orders most quickly. For example, two companies may produce the same product, but if one is able to deliver it to the customer in two days and the other in five days, the first company will make the sale and win over the customers. Time-based competition requires specifically designing the operations function for speed.

Supply Chain Management

▶ **Supply chain management (SCM)** Management of the flow of materials from suppliers to customers in order to reduce overall cost and increase responsiveness to customers.

Supply chain management (**SCM**) involves managing the flow of materials and information from suppliers and buyers of raw materials all the way to the final customer. The network of entities that is involved in producing and delivering a finished product to the final customer is called a supply chain. The objective is to have everyone in the chain work together to reduce overall cost and improve quality and service delivery. Supply chain management requires a team approach, with functions such as

marketing, purchasing, operations, and engineering all working together. This approach has been shown to result in more satisfied customers, meaning that everyone in the chain profits. SCM has become possible with the development of information technology (IT) tools that enable collaborative planning and scheduling. The technologies allow synchronized supply chain execution and design collaboration, which enables companies to respond better and faster to changing market needs. Numerous companies, including Dell Computer, Wal-Mart, and Toyota, have achieved world-class status by effectively managing their supply chains.

Courtesy N. Sanders

LINKS TO PRACTICE

John Wood Inc.
http://johnwoodnewyork.blogspot.com/

"They rowed in silence, the red cherry brightening up inside the pipe as smoke streamed out the side of his mouth. The bottle leered into their eyes when they pulled. Moonlight fell like icicles into the air, shimmering ripples of white ink upon the ocean surface, undulating up and down and wavering side to side."

(From *The Minister's Son* http://johnwoodnewyork.blogspot.com/)

SCM is as important in the service industry as it is in manufacturing, even in pure service industries such as the creative arts. Consider the publishing industry, which is responsible for delivering the creative art of literature to readers. The typical publishing supply chain, shown in Figure 1-7, consists of the author, the publisher, and the bookstore retailer. In the traditional publishing supply chain, the publisher is typically responsible for all the functions involved in transforming the author's literary creation into a tangible product to be placed on a bookshelf. This includes editing, printing, distribution, inventory management, and marketing.

Many writers have seen the traditional publishing supply chain as a setback to maintaining control and innovation over their art. Large publishing houses maintain control of many critical functions of the supply chain, resulting in the commoditization of the literary arts being sold in chain-type retailers. The net effect is often a homogenization of titles and writers across stores, creating a best-seller list that does not necessary reflect literary merit. This, in turn, produces a barrier for writers who have in fact created something highly personal out of the "sweat and travail of the human spirit" (Faulkner, Nobel Prize acceptance speech).

One novelist has innovatively overcome the large supply chain barrier between author and bookshelf. John Wood wrote an award-winning play at the age of 18 and his first novel, *Minister's Son*, at the age of 21, after which he decided to form his own

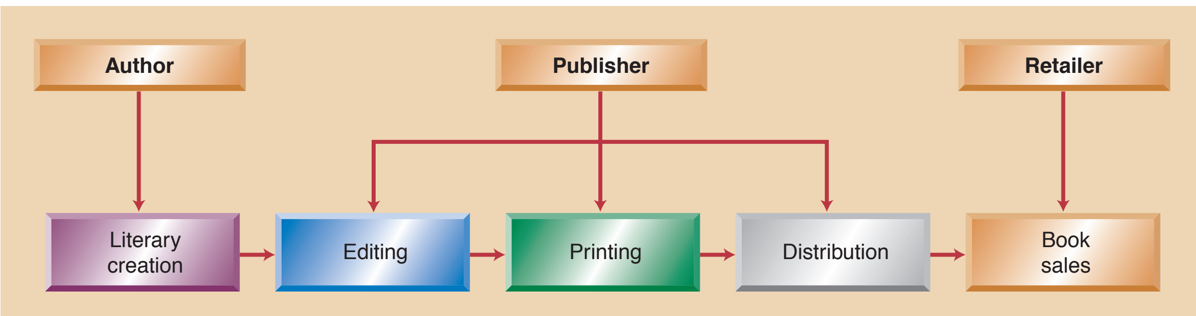


FIGURE 1-7

The traditional publishing supply chain

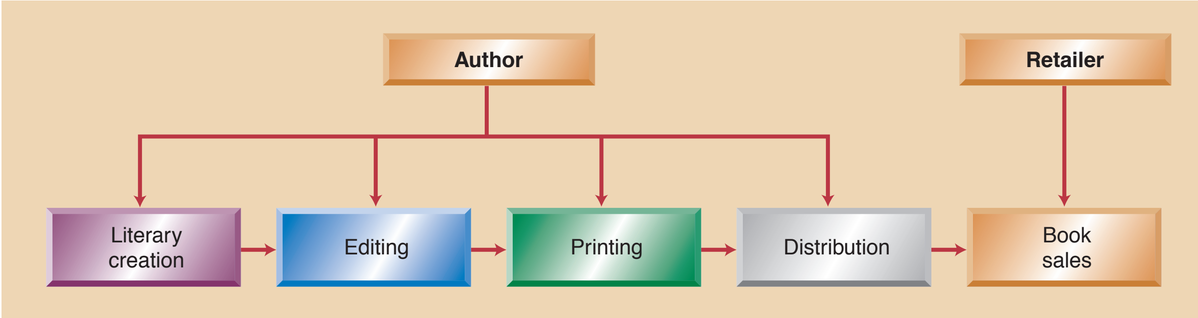


FIGURE 1-8

Author-controlled publishing supply chain

publishing company. By doing this, Wood enabled himself to maintain control of all aspects of his art, including retaining artisitic editorial prerogatives, such as choosing to print his writing in unique styles, rather than resorting to the same font and formatting dictated by a publishing house. This freedom is uniquely important to an artist such as Wood, who modifies his writing style to suit the subject and genre.

John Wood's storylines engage the controversial social issues of today, as well as grapple with the timeless and universal elements of the human condition. He uses a rich array of literary tropes and an inimitable sense of imagery in his writing. In addition to maintaining his artistic freedom, John Wood has been able to retain full legal rights of his own work. This supply chain is shown in Figure 1–8.

Global Marketplace

▶ **Global marketplace**
A trend in business focusing on customers, suppliers, and competitors from a global perspective.

Today businesses must think in terms of a **global marketplace** in order to compete effectively. This includes the way they view their customers, competitors, and suppliers. Key issues are meeting customer needs and getting the right product to markets as diverse as the Far East, Europe, or Africa. Operations management is responsible for most of these decisions. OM decides whether to tailor products to different customer needs, where to locate facilities, how to manage suppliers, and how to meet local government standards. Also, global competition has forced companies to reach higher levels of excellence in the products and services they offer. Regional trading agreements, such as the North American Free Trade Agreement (NAFTA), the European Union (EU), and the global World Trade Organization (WTO), guarantee continued competition on the international level.

Sustainability and Green Operations

▶ **Sustainability**
A trend in business to consciously reduce waste, recycle, and reuse products and parts.

There is increasing emphasis on the need to reduce waste, recycle, and reuse products and parts. This is known as ***sustainability*** or *green operations*. Society has placed great pressure on business to focus on air and water quality, waste disposal, global warming, and other environmental issues. Operations management plays a key role in redesigning processes and products in order to meet and exceed environmental quality standards. The importance of this issue is demonstrated by a set of standards termed ISO 14000. Developed by the International Organization for Standardization (ISO), these

standards provide guidelines and a certification program documenting a company's environmentally responsible actions.

Electronic Commerce

Electronic commerce (e-commerce) is the use of the Internet for conducting business activities, such as communication, business transactions, and data transfer. The Internet, developed from a government network called ARPANET created in 1969 by the U.S. Defense Department, has become an essential business medium since the late 1990s, enabling efficient communication between manufacturers, suppliers, distributors, and customers. It has allowed companies to reach more customers at a speed infinitely faster than ever before. It also has significantly cut costs, as it provides direct links between entities.

The electronic commerce that occurs between businesses, known as **B2B** (**business-to-business**) commerce, makes up the highest percentage of transactions. The most common B2B exchanges occur between companies and their suppliers, such as General Electric's Trading Process Network. A more familiar type of e-commerce occurs between businesses and their customers, known as **B2C** (**business-to-customer**) exchange, as engaged in by on-line retailers such as Amazon.com. E-commerce also occurs between customers, known as **C2C** (**customer-to-customer**) exchange, as on consumer auction sites such as eBay. E-commerce is creating virtual marketplaces that continue to change the way business functions.

▶ **Business-to-business (B2B)**
Electronic commerce between businesses.

▶ **Business-to-customers (B2C)**
Electronic commerce between businesses and their customers.

▶ **Customer-to-customer (C2C)**
Electronic commerce between customers.

Outsourcing and Flattening of the World

Outsourcing is obtaining goods or services from an outside provider. This can range from outsourcing of one aspect of the operation, such as shipping, to outsourcing an entire part of the manufacturing process. The practice has rapidly grown in recent years, as you can see in Figure 1-9. It has helped companies be more efficient by

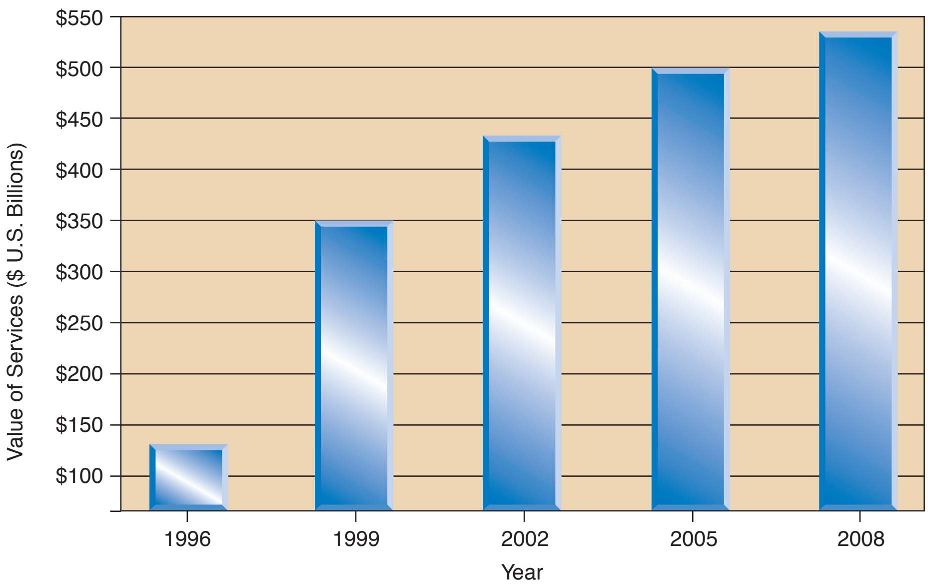


FIGURE 1-9

U.S. market for outsourcing services 1996–2008

focusing on what they do best. Outsourcing has been touted as the enabling factor that helps companies achieve the needed speed and flexibility to be competitive. Management guru Tom Peters has been quoted as saying, "Do what you do best and outsource the rest."

The convergence of technologies at the turn of this century has taken the concept of outsourcing to a new level. Massive investments in technology, such as worldwide broadband connectivity, the increasing availability and lower cost of computers, and the development of software such as e-mail, search engines, and other software, allow individuals to work together in real time from anywhere in the world. This has enabled countries like India, China, and many others to become part of the global supply chain for goods and services and has created a "flattening" of the world. Such "flattening," or leveling of the playing field, has enabled workers anywhere in the world to compete globally for intellectual work. The result has been the outsourcing of virtually any job imaginable. Manufacturers have outsourced software development and product design to engineers in India; accounting firms have outsourced tax preparation to India; even some hospitals have outsourced the reading of CAT scans to doctors in India and Australia. The "flattening" of the world has created a whole new level of global competition that is more intense than ever before.

TODAY'S OM ENVIRONMENT

Today's OM environment is very different from what it was just a few years ago. Customers demand better quality, greater speed, and lower costs. In order to succeed, companies have to be masters of the basics of operations management. To achieve this ability, many companies are implementing a concept called **lean systems**. Lean systems take a total system approach to creating an efficient operation and pull together best practice concepts, including just-in-time (JIT), total quality management (TQM), continuous improvement, resource planning, and supply chain management (SCM). The need for efficiency has also led many companies to implement large information systems called **enterprise resource planning** (**ERP**). ERP systems are large, sophisticated software programs for identifying and planning the enterprise-wide resources needed to coordinate all activities involved in producing and delivering products to customers.

▶ **Lean systems**
A concept that takes a total system approach to creating efficient operations.

▶ **Enterprise resource planning (ERP)**
Large, sophisticated software systems used for identifying and planning the enterprise-wide resources needed to coordinate all activities involved in producing and delivering products.

Applying best practices to operations management is not enough to give a company a competitive advantage. The reason is that in today's information age best practices are quickly passed to competitors. To gain an advantage over their competitors, companies are continually looking for ways to better respond to customers. This requires them to have a deep knowledge of their customers and to be able to anticipate their demands. The development of **customer relationship management** (**CRM**) has made it possible for companies to have this detailed knowledge. CRM encompasses software solutions that enable the firm to collect customer-specific data, information that can help the firm identify profiles of its most loyal customers and provide customer-specific solutions. Also, CRM software can be integrated with ERP software to connect customer requirements to the entire resource network of the company.

▶ **Customer relationship management (CRM)**
Software solutions that enable the firm to collect customer-specific data.

Another characteristic of today's OM environment is the increased use of **cross-functional decision making**, which requires coordinated interaction and decision making among the different business functions of the organization. Until recently, employees of a company made decisions in isolated departments, called "functional silos." Today many companies bring together experts from different departments into cross-functional teams to solve company problems. Employees from each function

▶ **Cross-functional decision making**
The coordinated interaction and decision making that occur among the different functions of the organization.

must interact and coordinate their decisions, which require employees to understand the roles of other business functions and the goals of the business as a whole, in addition to their own expertise.

OPERATIONS MANAGEMENT IN PRACTICE

Of all the business functions, operations is the most diverse in terms of the tasks performed. If you consider all the issues involved in managing a transformation process, you can see that operations managers are never bored. Who are operations managers and what do they do?

The head of the operations function in a company usually holds the title of vice president of operations, vice president of manufacturing, V.P., or director of supply chain operations and generally reports directly to the president or chief operating officer. Below the vice president level are midlevel managers: manufacturing manager, operations manager, quality control manager, plant manager, and others. Below these managers are a variety of positions, such as quality specialist, production analyst, inventory analyst, and production supervisor. These people perform a variety of functions: analyzing production problems, developing forecasts, making plans for new products, measuring quality, monitoring inventory, and developing employee schedules. Thus, there are many job opportunities in operations management at all levels of the company. In addition, operations jobs tend to offer high salaries, interesting work, and excellent opportunities for advancement. Many corporate CEOs today have come through the ranks of operations. For example, the third president and CEO of Wal-Mart from January 2000 to January 2009, H. Lee Scott, came from a background in operations and logistics. Also from the operations background are the former CEO of Home Depot, Bob Nardelli, and the former CEO of Lowe's, Robert Tillman.

As you can see, all business functions need information from operations management in order to perform their tasks. At the same time, operations managers are highly dependent on input from other areas. This process of information sharing is dynamic, requiring that managers work in teams and understand each other's roles.

WITHIN OM: HOW IT ALL FITS TOGETHER

Just as OM decisions are linked with those of other business functions, decisions *within* the OM function need to be linked together. We learned that OM is responsible for a wide range of strategic and tactical decisions. These decisions directly impact each other and need to be carefully linked together, following the company's strategic direction. In the Gourmet Wafers example we observed that decisions on product design are directly tied to process selection (Chapter 3). The reason is that a company's process needs to be capable of producing the desired product (Chapter 6). Similarly, the forecast of expected demand (Chapter 8) directly impacts functions such as capacity planning (Chapter 9), inventory management (Chapter 12), and scheduling (Chapter 15). These are just a few examples of linkages within the OM function.

Throughout this book we will study different OM functions and will learn how each impacts the other. You will realize that OM decisions are not made in isolation. Rather, each decision is intertwined with other business functions and other OM decisions.

OM ACROSS THE ORGANIZATION

Now that we know the role of the operations management function and the decisions that operations managers make, let's look at the relationship between operations and other business functions. As mentioned previously, most businesses are supported by three main functions: operations, marketing, and finance. Although these functions involve different activities, they must interact to achieve the goals of the organization. They must also follow the strategic direction developed at the top level of the organization. Figure 1-10 shows the flow of information from the top to each business function, as well as the flow between functions.

Many of the decisions made by operations managers are dependent on information from the other functions. At the same time, other functions cannot be carried out properly without information from operations. Figure 1-11 shows these relationships.

MKT

Marketing is not fully capable of meeting customer needs if marketing managers do not understand what operations can produce, what due dates it can and cannot meet, and what types of customization operations can deliver. The marketing department can develop an exciting marketing campaign, but if operations cannot produce the desired product, sales will not be made. In turn, operations managers need information about customer wants and expectations. It is up to them to design products with characteristics that customers find desirable, and they cannot do this without regular coordination with the marketing department.

FIN

Finance cannot realistically judge the need for capital investments, make-or-buy decisions, plant expansions, or relocation if finance managers do not understand operations concepts and needs. On the other hand, operations managers cannot make large financial expenditures without understanding financial constraints and methods of evaluating financial investments. It is essential for these two functions to work together and understand each other's constraints.

MIS

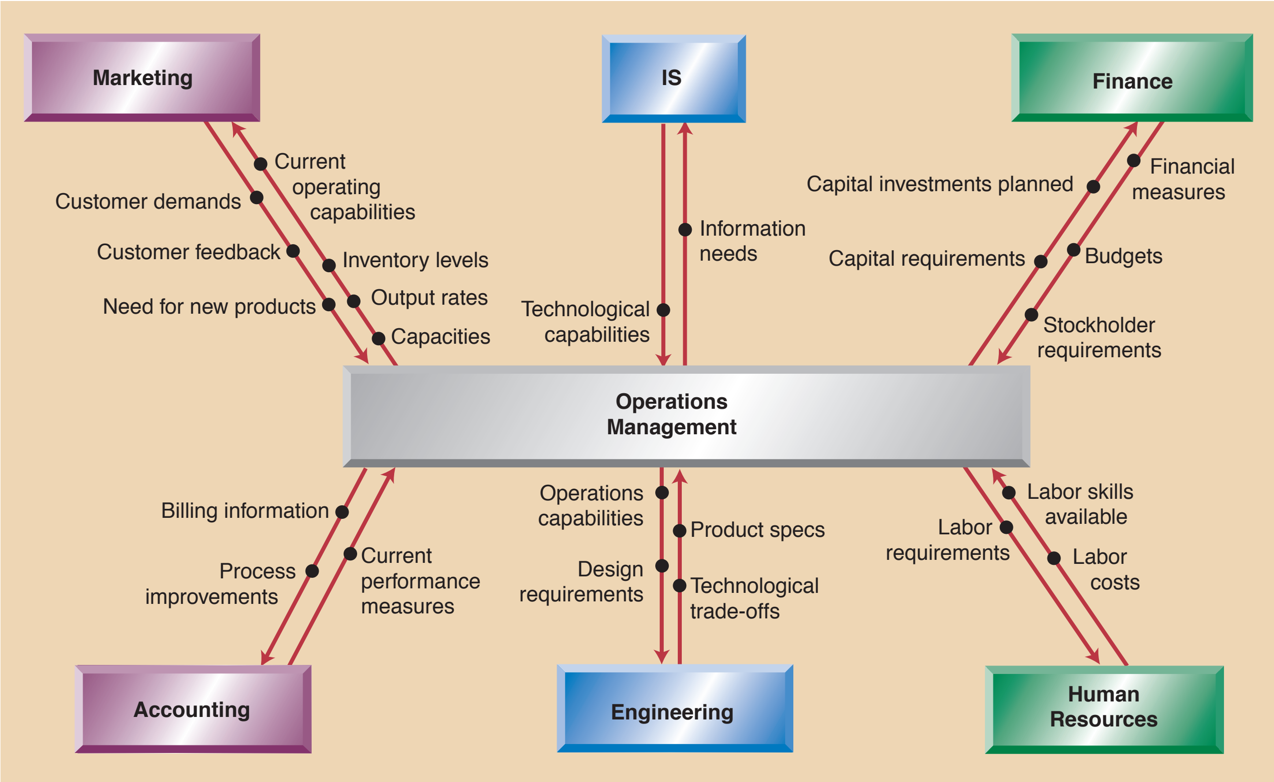
Information systems (IS) is a function that enables information to flow throughout the organization and allows OM to operate effectively. OM is highly dependent on information such as forecasts of demand, quality levels being achieved, inventory levels, supplier deliveries, and worker schedules. IS must understand the needs of OM in order to design an adequate information system. Usually, IS and OM work together to design an information network. This close relationship needs to be ongoing. IS must be capable of accommodating the needs of OM as they change in response to market demands. At

FIGURE 1-10

Organizational chart showing flow of information

FIGURE 1-11

Information flow between operations and other business functions



the same time, it is up to IS to bring the latest capabilities in information technology to the organization to enhance the functioning of OM.

Human resource managers must understand job requirements and worker skills if they are to hire the right people for available jobs. To manage employees effectively, operations managers need to understand job market trends, hiring and layoff costs, and training costs.

HRM

Accounting needs to consider inventory management, capacity information, and labor standards in order to develop accurate cost data. In turn, operations managers must communicate billing information and process improvements to accounting, and they depend heavily on accounting data for cost management decisions.

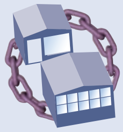
ACC

Engineering and other disciplines that are not in the business field are also tied to operations. Operations management provides engineering with the operations capabilities and design requirements, and engineering, in turn, provides valuable input on technological trade-offs and product specifications. These are essential for the product design process.

The coordinated interaction and decision making between all these functions and OM are needed for success in today's competitive environment. It is also important to extend this coordination to organizations that make up a supply chain, such as suppliers, manufacturers, and retailers. This is discussed in the following box.

THE SUPPLY CHAIN LINK

Today's companies understand that successfully managing their own OM functions is not enough to maintain leadership in a highly competitive marketplace. The reason is that every company is dependent on other members of the supply chain to successfully deliver the right product to the final customer in a timely and cost-effective manner. For example, a company is dependent on its suppliers for the delivery of raw materials and components in time to meet production needs. If these materials are delivered late or are of insufficient quality, production will be delayed. Similarly, a company depends on its distributors and retailers for the delivery of the product to the final customer. If these are not delivered on time, are damaged in the transportation process, or are poorly displayed at the retail location, sales will suffer. Also, if the OM function of other members of the supply chain is not managed properly, excess costs will result, which will be passed down to other members of the supply chain in the form of higher prices. Therefore, each company in the supply chain must successfully manage its OM function. Also, the companies that comprise a supply chain need to coordinate and link their OM functions so that the entire chain is operating in a seamless and efficient manner. Just consider the fact that most of the components Dell uses are warehoused within a 15-minute radius of its assembly plant and Dell is in constant communication with its suppliers. Dell considers this essential to its ability to produce and deliver components quickly.



Chapter Highlights

1. Operations management is the business function that is responsible for managing and coordinating the resources needed to produce a company's products and services. Without operations management there would be no products or services to sell.

2. The role of operations management is to transform organizational inputs—human resources, facilities, materials, technology, and information—into a company's finished goods or services.

3. Operations management is responsible for a wide range of decisions, ranging from strategic decisions, such as designing the unique features of a product and process, to tactical decisions, such as planning worker schedules.

4. Organizations can be divided into manufacturing and service operations, which differ in the tangibility of the product and the degree of customer contact. Manufacturing and service operations have very different operational requirements.

5. A number of historical milestones have shaped operations management into what it is today. Some of the more significant of these are the Industrial Revolution, scientific management, the human relations movement, management science, and the computer age.

6. OM is a highly important function in today's dynamic business environment. Among the trends that have had a significant impact on business are just-in-time, total quality management, reengineering, flexibility, time-based competition, supply chain management, a global marketplace, and environmental issues.

7. Operations managers need to work closely with all other business functions in a team format. Marketing needs to provide information about customer expectations. Finance needs to provide information about budget constraints. In turn, OM must communicate its needs and capabilities to the other functions.

Key Terms

operations management (OM) 3
role of operations management 3
value added 5
efficiency 5
manufacturing organizations 5
service organizations 5
strategic decisions 9
tactical decisions 9
Industrial Revolution 12
scientific management 13
Hawthorne studies 14
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customer-to-customer (C2C) 19
lean systems 20
enterprise resource planning (ERP) 20
customer relationship management (CRM) 20
cross-functional decision making 20

Discussion Questions

1. Define the term *operations management*.

2. Explain the decisions operations managers make and give three examples.

3. Describe the transformation process of a business. Give three examples. What constitutes the transformation process at an advertising agency, a bank, and a TV station?

4. What are the three major business functions, and how are they related to one another? Give specific examples.

5. What are the differences between strategic and tactical decisions, and how are they related to each other?

6. Find an article that relates to operations management in either the *Wall Street Journal, Fortune*, or *Business Week*. Come to class prepared to share with others what you learned in the article.

7. Examine the list of *Fortune* magazine's top 100 companies. Do most of these companies have anything in common? Are there industries that are most represented?

8. Identify the two major differences between service and manufacturing organizations. Find an example of a service and manufacturing company and compare them.

9. What are the three historical milestones in operations management? How have they influenced management?

10. Identify three current trends in operations management and describe them. How do you think they will change the future of OM?

11. Define the terms *total quality management, just-in-time*, and *reengineering*. What do these terms have in common?

12. Describe today's OM environment. How different is it from that of a few years ago? Identify specific features you think characterize today's OM environment.

13. Describe the impact of e-commerce on operations management. Identify the challenges posed by e-commerce on operations management.

14. Find a company you are familiar with and explain how it uses its operations management function. Identify what the company is doing correctly. Do you have any suggestions for improvement?

CASE: Hightone Electronics, Inc.

George Gonzales, operations director of Hightone Electronics, Inc. (HEI), sat quietly at the conference table overlooking the lobby of the corporate headquarters office in Palo Alto, California. He reflected on the board meeting that had just adjourned and the challenge that lay ahead for him. The board had just announced their decision to start an Internet-based division of HEI. Web-based purchasing in the electronics industry had been growing rapidly. The board felt that HEI needed to offer on-line purchasing to its customers in order to maintain its competitive position. The board looked to George to outline the key operations management decisions that needed to be addressed in creating a successful Internet-based business. The next board meeting was just a week away. He had his work cut out for him.

Hightone Electronics, Inc. was founded in Palo Alto, California over 50 years ago. Originally, the company provided radio components to small repair shops. Products were offered for sale through a catalog that was mailed to prospective customers every four months. The company built its reputation on high quality and service. As time passed, HEI began supplying more than just radio parts, adding items such as fuses, transformers, computers, and electrical testing equipment. The expansion of the product line had been coupled with an increase in the number and type of customers the company served. Although the traditional repair shops still remained a part of the company's market, technical schools, universities, and well-known corporations in the Silicon Valley were added to the list of customers.

Today HEI operates the Palo Alto facility with the same dedication to supplying quality products through catalog sales that it had when it was first founded. Customer service remains the top priority. HEI stocks and sells over 22,000 different items. Most customers receive their orders within 48 hours, and all components are warranted for a full year.

Expanding HEI to include Web-based purchasing seems to be a natural extension of catalog sales that the company already does successfully. George Gonzales agrees that the company has no choice but to move in this competitive direction. However, George does not agree with the opinion of the board that this would be "business as usual." He believes that there are many operations decisions that need to be identified and addressed. As he stated in the meeting, "Having a slick Web site is one thing, but making sure the right product is delivered to the right location is another. Operations is the key to making this happen." His challenge for the next board meeting was to identify the key operations decision and persuade the board that these issues needed serious consideration.

Case Questions

1. Explain why operations management is critical to the success of a business. Why would developing an Internet-based business require different operations consideration for HEI? Is George Gonzales correct in his assessment that this would not be "business as usual"?

2. Recall that HEI wishes to continue its reputation of high quality and service. Identify key operations management decisions that need to be considered. How different will these decisions be for the Internet business?

CASE: Creature Care Animal Clinic (A)

It has been three years since Dr. Julia Barr opened Creature Care Animal Clinic, a suburban veterinary clinic. Dr. Barr thought that by now she would be enjoying having her own practice. She had spent many years in college and worked to save money in order to start a business. Instead, she felt overwhelmed with business problems that were facing the clinic. She thought to herself: "I don't produce anything. I just provide a service doing something I enjoy. How can this be so complicated?"

Company Background

Dr. Barr opened Creature Care Animal Clinic as a veterinary clinic specializing in the care of dogs and cats. The clinic was set to operate Monday through Friday during regular business hours, with half days on Saturday and extended hours on Wednesday evening. Dr. Barr hired another full-time veterinarian, Dr. Gene Yen, a staff of three nurses, an office manager, and an office assistant. Both doctors were to work during the week and rotate the shift for Wednesday evenings and Saturdays. A similar schedule was set up for the nurses. The office manager worked during regular business hours, and the assistant worked on Wednesday evenings and Saturdays. Dr. Barr set up this schedule based on a clinic she had observed as a resident and thought it sounded reasonable.

Since the clinic was small, Dr. Barr did not have a formal system of inventory management. All physicians and nurses were allowed to place purchase orders based on need. Initially this system worked well, but after a few months problems started developing. Frequently, there was excess inventory of certain items, and in many cases there were multiple brands of the same product. Sometimes medications passed their expiration dates and had to be thrown away. At the same time, the clinic often unexpectedly ran out of stock of certain supplies and rush orders had to be placed. On one occasion, they ran so low on bandages that the assistant had to be sent to the local drug store.

Dr. Barr continued to rotate with Dr. Yen for coverage on Saturdays and Wednesday evenings. However, demand was increasing so rapidly on Saturdays that one doctor was not enough to provide needed coverage. Also, the Friday afternoon schedule was usually so packed that the staff frequently had to stay late in the evening. At the same time, there was little demand on Wednesday evenings and Dr. Barr found herself working on paperwork on those evenings, while the nurse and office assistant performed menial office tasks.

Case Questions

1. Identify the operations management problems that Dr. Barr is having at the clinic.
2. The schedule Dr. Barr set up worked well at the clinic where she was a resident. What are some of the reasons why it might not be working here?
3. Identify some of the reasons why the clinic is having inventory problems.
4. What should Dr. Barr have done differently to avoid some of the problems she is currently experiencing?
5. What suggestions would you make to Dr. Barr now?

INTERACTIVE CASE Virtual Company

www.wiley.com/college/reid

On-line Case: Cruise International, Inc.

Assignment: *Introduction to Cruise International, Inc.* You will be an intern for Cruise International, Inc. (CII). The company competes in the cruise industry in the small-ship, medium-ship, and large-ship markets. Your internship begins in a few weeks. Bob Bristol, your immediate boss, has asked you to become familiar with the cruise industry and its basic markets prior to beginning any of your assignments. This assignment will enhance your knowledge of the material in Chapter 1 of your textbook while preparing your future assignments.

To access the Web site:

- Go to **www.wiley.com/college/reid**
- Click **Student Companion Site**
- Click **Virtual Company**
- Click **Consulting Assignments**
- Click **Welcome to Cruise International, Inc.**

INTERNET CHALLENGE Demonstrating Your Knowledge of OM

Visit the Web sites of at least one service and one manufacturing company. For each company, identify at least five characteristic OM decisions and show your results in a table. Which decisions are strategic and which are tactical? How do these decisions differ between the two companies? Here are some Web sites to consider.

Select service company Web sites:

www.ritzcarlton.com (Ritz-Carlton Hotel)
www.sprint.com (Sprint Corporation)
www.yellowcorp.com (Yellow Corporation)
www.kmart.com (Kmart Corporation)
www.yahoo.com (Yahoo!)

Select manufacturing company Web sites:

www.saturn.com (Saturn Corporation)
www.alcoa.com (Alcoa Inc.)
www.milliken.com (Milliken & Company)
www.Intel.com (Intel Corporation)
www.ge.com (General Electric Company)

On-line Resources

Companion Website www.wiley.com/college/reid

- Take interactive *practice quizzes* to assess your knowledge and help you study in a dynamic way
- Review *PowerPoint slides* or print slides for notetaking
- Access the *Virtual Company: Cruise International, Inc.*
- Find links for *Additional Web Resources* for this chapter
  APICS, *www.apics.org*
  Council of Logistics Management, *www.clml.org*

Additional Resources Available Only in WileyPLUS

- Use the *e-Book* and launch directly to all interactive resources
- Take the interactive *Quick Test* to check your understanding of the chapter material and get immediate feedback on your responses
- Check your understanding of the key vocabulary in the chapter with *Interactive Flash Cards*
- Use the *Animated Demo Problems* to review key problem types
- Practice for your test with *additional problem sets*
- *And more!*

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CHAPTER 2

Operations Strategy and Competitiveness

Before studying this chapter you should know or, if necessary, review

1. The role of the OM function in organizations, Chapter 1, pp. 2–5.
2. Differences between strategic and tactical decisions, Chapter 1, pp. 7–10.

LEARNING OBJECTIVES

After studying this chapter you should be able to

1. Define the role of business strategy.
2. Explain how a business strategy is developed.
3. Explain the role of operations strategy in the organization.
4. Explain the relationship between business strategy and operations strategy.
5. Describe how an operations strategy is developed.
6. Identify competitive priorities of the operations function.
7. Explain the strategic role of technology.
8. Define productivity and identify productivity measures.
9. Compute productivity measures.

CHAPTER OUTLINE

WHAT'S IN OM FOR ME?

ACC FIN MKT OM HRM MIS

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To maintain a competitive position in the marketplace, a company must have a long-range plan. This plan needs to include the company's long-term goals, an understanding of the marketplace, and a way to differentiate the company from its competitors. All other decisions must support this long-range plan. Otherwise, each person in the company would pursue goals that he or she considered important, and the company would quickly fall apart.

The functioning of a football team on the field is similar to the functioning of a business and provides a good example of the importance of a plan or vision. Before the plays are made, the team prepares a game strategy. Each player on the team must perform a particular role to support this strategy. The strategy is a "game plan" designed so that the team can win. Imagine what would occur if individual players decided to do plays that they thought were appropriate. Certainly the team's chance of winning would not be very high. A successful football team is a unified group of players using their individual skills in support of a winning strategy. The same is true of a business.

The long-range plan of a business, designed to provide and sustain shareholder value, is called the **business strategy**. For a company to succeed, the business strategy must be supported by each of the individual business functions, such as operations, finance, and marketing. **Operations strategy** is a long-range plan for the operations function that specifies the design and use of resources to support the business strategy. Just as the players on a football team support the team's strategy, the role of everyone in the company is to do his or her job in a way that supports the business strategy.

▶ **Business strategy**
A long-range plan for a business.

▶ **Operations strategy**
A long-range plan for the operations function that specifies the design and use of resources to support the business strategy.

Let's look at two companies operating in the same industry, but with very different business strategies. The first is Southwest Airlines, which has a strategy to compete on cost. Southwest offers low-cost services aimed at price-sensitive customers. To support this strategy, every aspect of Southwest's operation is focused on cutting costs out of the system. Later in this chapter we will look at specific operations decisions that Southwest has made to achieve this. The second company is Singapore Airlines, which has a strategy to compete on service. To support this strategy the airline offers free drinks, complimentary headsets, meals prepared by gourmet chefs, comfortable cabins, and even the biggest bed in business class, called the "spacebed." Both airlines began as regional carriers, and each has grown to be a highly successful major airline. Although they are in the same industry, their operations decisions are different because of their different business strategies.

In today's highly competitive, Internet-based, and global marketplace, it is important for companies to have a clear plan for achieving their goals. In this chapter we discuss the role of operations strategy, its relationship to the business strategy, and ways in which the operations function can best support the business strategy. We conclude with a discussion of productivity, one measure of a company's competitiveness.

THE ROLE OF OPERATIONS STRATEGY

HRM MIS

The role of operations strategy is to provide a plan for the operations function so that it can make the best use of its resources. Operations strategy specifies the policies and plans for using the organization's resources to support its long-term competitive strategy. Figure 2-1 shows this relationship.

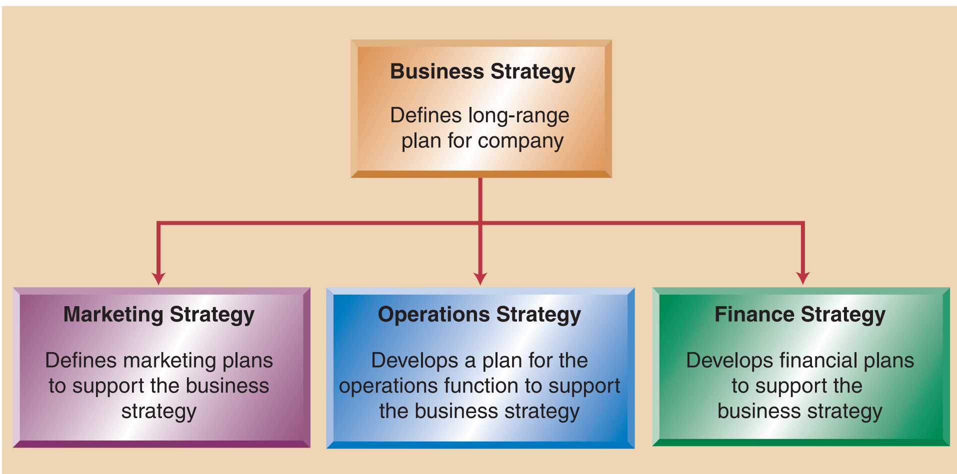
Remember that the operations function is responsible for managing the resources needed to produce the company's goods and services. Operations strategy is the plan that specifies the design and use of resources to support the business strategy. This includes the location, size, and type of facilities available; worker skills and talents required; use of technology, special processes needed, special equipment; and quality control methods. The operations strategy must be aligned with the company's business strategy and enable the company to achieve its long-term plan. For example, the business strategy of FedEx, the world's largest provider of expedited delivery services, is to compete on time and dependability of deliveries. The operations strategy of FedEx developed a plan for resources to support its business strategy. To provide speed of delivery, FedEx acquired its own fleet of airplanes. To provide dependability of deliveries, FedEx invested in a sophisticated bar-code technology to track all packages.

The Importance of Operations Strategy

Operations strategy did not come to the forefront until the 1970s. Up to that time, U.S. companies emphasized mass production of standard product designs. There were no serious international competitors, and U.S. companies could pretty much sell anything

FIGURE 2-1

Relationship between the business strategy and the functional strategies



they produced. However, that changed in the 1970s and 1980s. Japanese companies began offering products of superior quality at lower cost, and U.S. companies lost market share to their Japanese counterparts. In an attempt to survive, many U.S. companies copied Japanese approaches. Unfortunately, merely copying these approaches often proved unsuccessful; it took time to really understand the Japanese approaches. It became clear that Japanese companies were more competitive because of their operations strategy; that is, all their resources were specifically designed to directly support the company's overall strategic plan.

Harvard Business School professor Michael Porter says that companies often do not understand the differences between *operational efficiency* and *strategy*. Operational efficiency is performing operations tasks well, even better than competitors. Strategy, on the other hand, is a plan for competing in the marketplace. An analogy might be that of running a race efficiently, but the wrong race. Strategy is defining in what race you will win. Operational efficiency and strategy must be aligned; otherwise, you may be *very efficiently performing the wrong task*. The role of operations strategy is to make sure that all the tasks performed by the operations function are the *right tasks*. Consider a software company that recently invested millions of dollars in developing software with features not provided by competitors, only to discover that these were features customers did not particularly want.

Now that we know the meaning of *business strategy* and *operations strategy* and their importance, let's look at how a company would go about developing a business strategy. Then we will see how an operations strategy would be developed to support the company's business strategy.

DEVELOPING A BUSINESS STRATEGY

A company's business strategy is developed after its managers have considered many factors and have made some strategic decisions. These include developing an understanding of what business the company is in (the company's *mission*), analyzing and developing an understanding of the market (*environmental scanning*), and identifying the company's strengths (*core competencies*). These three factors are critical to the development of the company's long-range plan, or business strategy. In this section we describe each of these elements in detail and show how they are combined to formulate the business strategy.

Mission

Every organization, from IBM to the Boy Scouts, has a mission. The **mission** is a statement that answers three overriding questions:

- *What* business will the company be in ("selling personal computers," "operating an Italian restaurant")?
- *Who* will the customers be, and what are the expected customer attributes ("homeowners," "college graduates")?
- *How* will the company's basic beliefs define the business ("gives the highest customer service," "stresses family values")?

▶ **Mission**
A statement defining *what* business an organization is in, *who* its customers are, and *how* its core beliefs shape its business.

Following is a list of some well-known companies and parts of their mission statements:

Dell Computer Corporation: "to be the most successful computer company in the world"
Delta Air Lines: "worldwide airlines choice"
IBM: "translate advanced technologies into values for our customers as the world's largest information service company"
Lowe's: "helping customers build, improve and enjoy their homes"
Ryder: "offers a wide array of logistics services, such as distribution management, domestically and globally"

The mission defines the company. In order to develop a long-term plan for a business, you must first know exactly what business you are in, what customers you are serving, and what your company's values are. If a company does not have a well-defined mission, it may pursue business opportunities about which it has no real knowledge or that are in conflict with its current pursuits, or it may miss opportunities altogether.

For example, Dell Computer Corporation has become a leader in the computer industry in part by following its mission. If it did not follow its mission, Dell might decide to pursue other opportunities, such as producing mobile telephones similar to those manufactured by Motorola and Nokia. Although there is a huge market for mobile telephones, it is not consistent with Dell's mission of focusing on computers.

Environmental Scanning

A second factor to consider is the external environment of the business. This includes trends in the market, in the economic and political environment, and in society. These trends must be analyzed to determine business opportunities and threats. **Environmental scanning** is the process of monitoring the external environment. To remain competitive, companies have to continuously monitor their environment and be prepared to change their business strategy, or long-range plan, in light of environmental changes.

▶ **Environmental scanning**
Monitoring the external environment for changes and trends to determine business opportunities and threats.

What Does Environmental Scanning Tell Us? Environmental scanning allows a company to identify *opportunities* and *threats*. For example, through environmental scanning we could see gaps in what customers need and what competitors are doing to meet those needs. A study of these gaps could reveal an opportunity for our company, and we could design a plan to take advantage of it. On the other hand, our company may currently be a leader in its industry, but environmental scanning could reveal competitors that are meeting customer needs better—for example, by offering a wider array of services. In this case, environmental scanning would reveal a threat and we would have to change our strategy so as not to be left behind. Just because a company is an industry leader today does not mean it will continue to be a leader in the future. In the 1970s Sears, Roebuck and Company was a retail leader, but it fell behind the pack in the 1990s.

What Are Trends in the Environment? The external business environment is always changing. To stay ahead of the competition, a company must constantly look out for trends or changing patterns in the environment, such as *marketplace trends*. These

might include changes in customer wants and expectations and ways in which competitors are meeting those expectations. For example, in the computer industry customers are demanding speed of delivery, high quality, and low price. Dell has become a leader in the industry because of its speed of delivery and low price. Other computer giants, such as Compaq, have had to redesign their business and operations strategies to compete with Dell. Otherwise, they would be left behind. It is through environmental scanning that companies like Compaq can see trends in the market, analyze the competition, and recognize what they need to do to remain competitive.

There are many other types of trends in the marketplace. For example, we are seeing changes in the use of technology, such as point-of-sale scanners, automation, computer-assisted processing, electronic purchasing, and electronic order tracking. One rapidly growing trend is e-commerce. For retailers like The Gap, Eddie Bauer, Fruit of the Loom, Inc., Barnes & Noble, and others, e-commerce has become a significant part of their business. Victoria's Secret has even used the Internet to conduct a fashion show in order to boost sales. Some companies began using e-commerce early in their development. Others, like Sears, Roebuck, waited and then found themselves working hard to catch up to the competition.

In addition to market trends, environmental scanning looks at economic, political, and social trends that can affect the business. *Economic trends* include recession, inflation, interest rates, and general economic conditions. Suppose that a company is considering obtaining a loan in order to purchase a new facility. Environmental scanning could show that interest rates are particularly favorable and that this may be a good time to go ahead with the purchase.

Political trends include changes in the political climate—local, national, and international—that could affect a company. For example, the creation of the European Union has had a significant impact on strategic planning for such global companies as IBM, Hewlett-Packard, and PepsiCo. Similarly, changes in trade relations with China have opened opportunities that were not available earlier. There has been a change in how companies view their environment, a shift from a national to a global perspective. Companies seek customers and suppliers all over the globe. Many have changed their strategies in order to take advantage of global opportunities, such as forming partnerships with international firms, called *strategic alliances*. For example,

Bryan and Cherry Alexander/Alamy

Pepsi seeks customers and suppliers all over the globe.

companies like Motorola and Xerox want to take advantage of opportunities in China and are developing strategic alliances to help them break into that market.

Finally, *social trends* are changes in society that can have an impact on a business. An example is the awareness of the dangers of smoking, which has made smoking less socially acceptable. This trend has had a huge impact on the tobacco industry. In order to survive, many of these companies have changed their strategy to focus on customers overseas, where smoking is still socially acceptable, or have diversified into other product lines.

Core Competencies

▶ **Core competencies** The unique strengths of a business.

The third factor that helps define a business strategy is an understanding of the company's strengths. These are called **core competencies**. In order to formulate a long-term plan, the company's managers must know the competencies of their organization. Core competencies could include special skills of workers, such as expertise in providing customized services or knowledge of information technology. Another example might be flexible facilities that can handle the production of a wide array of products. To be successful, a company must compete in markets where its core competencies will have value. Table 2-1 shows a list of some core competencies that companies may have.

Highly successful firms develop a business strategy that takes advantage of their core competencies or strengths. To see why it is important to use core competencies, think of a student developing plans for a successful professional career. Let's say that this student is particularly good at mathematics but not as good in verbal communication and persuasion. Taking advantage of core competencies would mean developing a career strategy in which the student's strengths could provide an advantage, such as engineering or computer science. On the other hand, pursuing a career in marketing would place the student at a disadvantage because of a relative lack of skills in persuasion.

Increased global competition has driven many companies to clearly identify their core competencies and outsource those activities considered noncore. Recall from

TABLE 2-1

Organizational Core Competencies

1. Workforce	Highly trained Responsive in meeting customer needs Flexible in performing a variety of tasks Strong technical capability Creative in product design
2. Facilities	Flexible in producing a variety of products Technologically advanced An efficient distribution system
3. Market Understanding	Skilled in understanding customer wants and predicting market trends
4. Financial Know-how	Skilled in attracting and raising capital
5. Technology	Use of latest production technology Use of information technology Quality control techniques

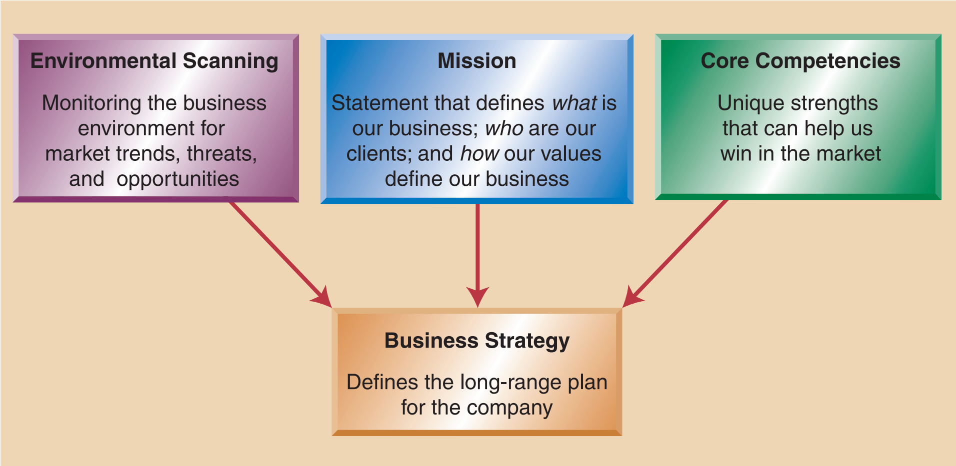


FIGURE 2-2

Three inputs in developing a business strategy

Chapter 1 that outsourcing is obtaining goods or services from an outside provider. By outsourcing noncore activities, a company can focus on its core competencies. For example, Meijer, a grocery and general merchandise retailer, outsources the transportation of all its merchandise to a company called Total Logistics Control (TLC). TLC is responsible for all deliveries, route scheduling, and all activities involved in maintaining a fleet of trucks, allowing Meijer to focus on its core competencies.

Putting It Together

Figure 2-2 shows how the mission, environmental scanning, and core competencies help in the formulation of the business strategy. This is an ongoing process that is constantly allowed to change. As environmental scanning reveals changes in the external environment, the company may need to change its business strategy to remain competitive while taking advantage of its core competencies and staying within its mission.

LINKS TO PRACTICE

Dell Computer Corporation
www.dell.com

GEORGE FREY/
Bloomberg News/
Landov

Let's look at how Dell Computer Corporation combined its mission, environmental scanning, and core competencies to develop a highly successful business strategy. Dell's mission is to "be the most successful computer company in the world at delivering the best customer experience in markets we serve. In doing so, Dell will meet customer expectations of: highest quality, leading technology, competitive pricing, individual and company accountability, best-in-class service and support, flexible customization capability, superior corporate citizenship, and financial stability." The mission defined what business Dell is in: highest quality, leading technology, computer company. It also defined Dell's customers: focus on markets served. Finally, it defined how Dell would do this: through competitive pricing, best-in-class service and support, and flexible customization capability. You can see how this mission defines Dell as a company.

An environmental scan revealed that competing computer manufacturers, such as IBM and Compaq, used intermediate resellers to sell computers. This led to higher inventory, higher costs, and slower responsiveness to customer wants. Michael Dell's idea was to sell directly to the customer and be able to put together exactly the system the customer wanted within a short time. Dell defined its core competencies as flexible manufacturing and the latest technological offering. Together, the mission, environmental scan, and core competencies were used to develop a competitive business strategy that provides customized computer solutions to customers within 36 hours at a highly competitive price.

Dell's business strategy was to take advantage of an opportunity in the market. However, to implement this strategy, the company needed to develop an operations strategy that arranged all the resources in ways that would support the business strategy. Operations strategy designs a plan for resources in order to take the business strategy from concept to reality. In the next section we look at how an operations strategy is developed.

Before You Go On

Make sure that you understand the role of the *business strategy* in defining a company's long-term plan. Without a business strategy the company would have no overriding plan. Such a plan acts like a compass, pointing the company in the right direction. To be effective, a long-range plan must be supported by each of the business functions. The *operations strategy* looks at the business strategy and develops a long-range plan specifically for the operations function. In the next section we will see how the operations strategy is developed.

DEVELOPING AN OPERATIONS STRATEGY

Once a business strategy has been developed, an operations strategy must be formulated. This will provide a plan for the design and management of the operations function in ways that support the business strategy. The operations strategy relates the business strategy to the operations function. The operations strategy focuses on specific capabilities of the operation that give the company a competitive edge. These capabilities are called **competitive priorities**. By excelling in one of these capabilities, a company can become a winner in its market. These competitive priorities and their relationship to the design of the operations function are shown in Figure 2-3. Each part of this figure is discussed next.

▶ **Competitive priorities** Capabilities that the operations function can develop in order to give a company a competitive advantage in its market.

Competitive Priorities

Operations managers must work closely with marketing in order to understand the competitive situation in the company's market before they can determine which competitive priorities are important. There are four broad categories of competitive priorities:

▶ **Cost** A competitive priority focusing on low cost.

1. Cost Competing based on **cost** means offering a product at a low price relative to the prices of competing products. The need for this type of competition emerges from the business strategy. The role of the operations strategy is to develop a plan for the use of resources to support this type of competition. Note that a low-cost strategy can result in a higher profit margin, even at a competitive price. Also, low cost does not imply low quality. Let's look at some specific characteristics of the operations function we might find in a company competing on cost.

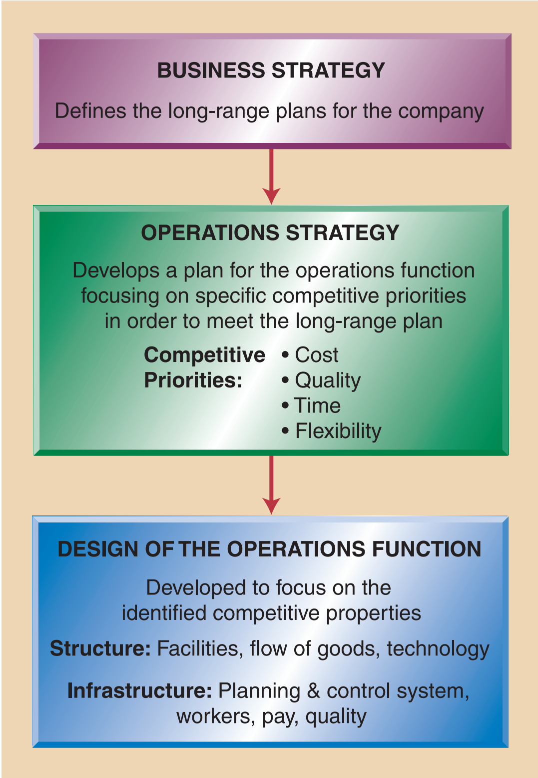


FIGURE 2-3

Operations strategy and the design of the operations function

To develop this competitive priority, the operations function must focus primarily on cutting costs in the system, such as costs of labor, materials, and facilities. Companies that compete based on cost study their operations system carefully to eliminate all waste. They might offer extra training to employees to maximize their productivity and minimize scrap. Also, they might invest in automation in order to increase productivity. Generally, companies that compete based on cost offer a narrow range of products and product features, allow for little customization, and have an operations process that is designed to be as efficient as possible.

LINKS TO PRACTICE

Southwest Airlines Company
www.southwest.com

Justin Sullivan/Staff/
Getty Images, Inc.

A company that successfully competes on cost is Southwest Airlines. Southwest's entire operations function is designed to support this strategy. Facilities are streamlined: only one type of aircraft is used, and flight routes are generally short. This serves to minimize costs of scheduling crew changes, maintenance, inventories of parts, and many administrative costs. Unnecessary costs are completely eliminated: there are no meals, printed boarding passes, or seat assignments. Employees are trained to perform many functions and use a team approach to maximize customer service. Because of this strategy, Southwest has been a model for the airline industry for a number of years.

▶ **Quality**
A competitive priority focusing on the quality of goods and services.

2. Quality Many companies claim that **quality** is their top priority, and many customers say that they look for quality in the products they buy. Yet quality has a subjective meaning; it depends on who is defining it. For example, to one person quality could mean that the product lasts a long time, such as with a Volvo, a car known for its longevity. To another person quality might mean high performance, such as a BMW. When companies focus on quality as a competitive priority, they are focusing on the dimensions of quality that are considered important by their customers.

Quality as a competitive priority has two dimensions. The first is *high-performance design*. This means that the operations function will be designed to focus on aspects of quality such as superior features, close tolerances, high durability, and excellent customer service. The second dimension is *goods and services consistency*, which measures how often the goods or services meet the exact design specifications. A strong example of product consistency is McDonald's, where we know we can get the same product every time at any location. Companies that compete on quality must deliver not only high-performance design but goods and services consistency as well.

A company that competes on this dimension needs to implement quality in every area of the organization. One of the first aspects that needs to be addressed is *product design quality*, which involves making sure the product meets the requirements of the customer. A second aspect is *process quality*, which deals with designing a process to produce error-free products. This includes focusing on equipment, workers, materials, and every other aspect of the operation to make sure it works the way it is supposed to. Companies that compete based on quality have to address both of these issues: the product must be designed to meet customer needs, and the process must produce the product exactly as it is designed.

To see why product and process quality are both important, let's say that your favorite fast-food restaurant has designed a new sandwich called the "Big Yuck." The restaurant could design a process that produces a perfect "Big Yuck" every single time. But if customers find the "Big Yuck" unappealing, they will not buy it. The same would be true if the restaurant designed a sandwich called the "Super Delicious" to meet the desires of its customers. Even if the "Super Delicious" were exactly what the customers wanted, if the process did not produce the sandwich the way it was designed, often making it soggy and cold instead, customers would not buy it. Remember that the product needs to be designed to meet customer wants and needs, and the process needs to be designed to produce the exact product that was intended, consistently without error.

▶ **Time**
A competitive priority focusing on speed and on-time delivery.

3. Time **Time** or speed is one of the most important competitive priorities today. Companies in all industries are competing to deliver high-quality products in as short a time as possible. Companies like FedEx, LensCrafters, United Parcel Service (UPS), and Dell compete based on time. Today's customers don't want to wait, and companies that can meet their need for fast service are becoming leaders in their industries.

Making time a competitive priority means competing based on all time-related issues, such as *rapid delivery* and *on-time delivery*. Rapid delivery refers to how quickly an order is received; on-time delivery refers to how often deliveries are made on time. Another time-competitive priority is development speed, which is the time needed to take an idea to the marketplace. This is especially critical in technology and computer software fields. When time is a competitive priority, the job of the operations function is to critically analyze the system and combine or eliminate processes in order to save time. Often companies use technology to speed up processes, rely on a flexible workforce to meet peak demand periods, and eliminate unnecessary steps in the production process.

FedEx is an example of a company that competes based on time. The company's claim is to "absolutely, positively" deliver packages on time. To support this strategy, the operation function had to be designed to promote speed. Bar-code technology is used to speed up processing and handling, and the company uses its own fleet of airplanes. FedEx relies on a very flexible part-time workforce, such as college students who are willing to work a few hours at night. FedEx can call on this part-time workforce at a moment's notice, providing the company with a great deal of flexibility. This allows FedEx to cover workforce requirements during peak periods without having to schedule full-time workers.

LINKS TO PRACTICE

FedEx Corporation
www.federalexpress.com

4. Flexibility As a company's environment changes rapidly, including customer needs and expectations, the ability to readily accommodate these changes can be a winning strategy. This is **flexibility**. There are two dimensions of flexibility. One is the ability to offer a wide variety of goods or services and customize them to the unique needs of clients. This is called *product flexibility*. A flexible system can quickly add new products that may be important to customers or easily drop a product that is not doing well. Another aspect of flexibility is the ability to rapidly increase or decrease the amount produced in order to accommodate changes in the demand. This is called *volume flexibility*.

▶ **Flexibility**
A competitive priority focusing on offering a wide variety of goods or services.

You can see the meaning of flexibility when you compare ordering a suit from a custom tailor to buying it off the rack at a retailer. Another example would be going to a fine restaurant and asking to have a meal made just for you, versus going to a fast-food restaurant and being limited to items on the menu. The custom tailor and the fine restaurant are examples of companies that are flexible and will accommodate customer wishes. Another example of flexibility is Empire West Inc., a company that makes a variety of products out of plastics, depending on what customers want. Empire West makes everything from plastic trays to body guards for cars.

Companies that compete based on flexibility often cannot compete based on speed because it generally requires more time to produce a customized product. Also, flexible companies typically do not compete based on cost because it may take more resources to customize the product. However, flexible companies often offer greater customer service and can meet unique customer requirements. To carry out this strategy, flexible companies tend to have more general-purpose equipment that can be used to make many different kinds of products. Also, workers in flexible companies tend to have higher skill levels and can often perform many different tasks in order to meet customer needs.

The Need for Trade-Offs

You may be wondering why the operations function needs to give special focus to some priorities but not all. Aren't all the priorities important? As more resources are dedicated to one priority, fewer resources are left for others. The operations function

▶ **Trade-off**
The need to focus more on one competitive priority than on others.

must place emphasis on those priorities that directly support the business strategy. Therefore, it needs to make **trade-offs** between the different priorities. For example, consider a company that competes on using the highest quality component parts in its products. Due to the high quality of parts, the company may not be able to offer the final product at the lowest price. In this case, the company has made a trade-off between quality and price. Similarly, a company that competes on making each product individually based on customer specifications will likely not be able to compete on speed. Here, the trade-off has been made between flexibility and speed.

It is important to know that every business must achieve a basic level of each of the priorities, even though its primary focus is only on some. For example, even though a company is not competing on low price, it still cannot offer its products at such a high price that customers would not want to pay for them. Similarly, even though a company is not competing on time, it still has to produce its product within a reasonable amount of time; otherwise, customers will not be willing to wait for it.

One way that large facilities with multiple products can address the issue of trade-offs is using the concept of plant-within-a-plant (PWP), introduced by well-known Harvard professor Wickham Skinner. The PWP concept suggests that different areas of a facility be dedicated to different products with different competitive priorities. These areas should be physically separated from one another and should even have their own separate workforce. As the term suggests, there are multiple plants within one plant, allowing a company to produce different products that compete on different priorities. For example, hospitals use PWP to achieve specialization or focus in a particular area, such as the cardiac unit, oncology, radiology, surgery, or pharmacy. Similarly, department stores use PWP to isolate departments, such as the Sears auto service department versus its optometry center.

Order Winners and Qualifiers

▶ **Order qualifiers**
Competitive priorities that must be met for a company to qualify as a competitor in the marketplace.

▶ **Order winners**
Competitive priorities that win orders in the marketplace.

To help a company decide which competitive priorities to focus on, it is important to distinguish between *order winners* and *order qualifiers*, which are concepts developed by Terry Hill, a professor at Oxford University. **Order qualifiers** are those competitive priorities that a company has to meet if it wants to do business in a particular market. **Order winners**, on the other hand, are the competitive priorities that help a company win orders in the market. Consider a simple restaurant that makes and delivers pizzas. Order qualifiers might be low price (say, less than $10.00) and quick delivery (say, under 15 minutes) because this is a standard that has been set by competing pizza restaurants. The order winners may be "fresh ingredients" and "home-made taste." These characteristics may differentiate the restaurant from all the other pizza restaurants. However, regardless of how good the pizza, the restaurant will not succeed if it does not meet the minimum standard for order qualifiers. Knowing the order winners and order qualifiers in a particular market is critical to focusing on the right competitive priorities.

It is important to understand that order winners and order qualifiers change over time. Often when one company in a market is successfully competing using a particular order winner, other companies follow suit over time. The result is that the order winner becomes an industry standard, or an order qualifier. To compete successfully, companies then have to change their order winners to differentiate themselves. An excellent example of this occurred in the auto industry. Prior to the 1970s, the order-winning criterion in the American auto industry was price. Then the Japanese

automobile manufacturers entered the market competing on quality at a reasonable price. The result was that quality became the new order winner and price became an order qualifier, or an expectation. Then by the 1980s American manufacturers were able to raise their level of quality to be competitive with the Japanese. Quality then became an order qualifier, as everyone had the same quality standard.

Translating Competitive Priorities into Production Requirements

Operations strategy makes the needs of the business strategy specific to the operations function by focusing on the right competitive priorities. Once the competitive priorities have been identified, a plan is developed to support those priorities. The operations strategy will specify the design and use of the organization's resources; that is, it will set forth specific operations requirements. These can be broken down into two categories.

1. **Structure—**Operations decisions related to the design of the production process, such as characteristics of facilities used, selection of appropriate technology, and flow of goods and services through the facility.
2. **Infrastructure—**Operations decisions related to the planning and control systems of the operation, such as organization of the operations function, skills and pay of workers, and quality control approaches.

▶ **Structure**
Operations decisions related to the design of the production process, such as facilities, technology, and flow of goods and services through the facility.

▶ **Infrastructure**
Operations decisions related to the planning and control systems of the operation, such as organization of operations, skills and pay of workers, and quality measures.

Together, the structure and infrastructure of the production process determine the nature of the company's operations function.

The structure and infrastructure of the production process must be aligned to enable the company to pursue its long-term plan. Suppose we determined that *time* or *speed* of delivery is the order winner in the marketplace and the competitive priority we need to focus on. We would then design the production process to promote speedy product delivery. This might mean having a system that does not necessarily produce the product at the absolutely lowest cost, possibly because we need costlier or extra equipment to help us focus on speed. The important thing is that every aspect of production of a product or delivery of a service needs to focus on supporting the competitive priority. However, we cannot neglect the other competitive priorities. A certain level of order qualifiers must be achieved just to remain in the market. The issue is not one of focusing on one priority to the exclusion of the others. Rather, it is a matter of degree.

Let's return to the example of Dell Computer Corporation. Earlier we explained how Dell used its mission, environmental scanning, and core competencies to develop its business strategy. But to make this business plan a reality, the company needed to develop an operations strategy to create its structure and infrastructure. The focus was on customer service, cost, and speed. Dell set up a system in which customers could order computers directly from the company, without going through an intermediary, such as a retailer. An operations system was designed so that ordering of components and assembly of computers did not occur until an order was actually placed. This kept costs low because Dell did not have computers sitting in inventory. A warehousing system was designed so that when components were needed, suppliers would deliver them to the plant within 15 minutes; in contrast, competitors like IBM and Compaq must wait hours or even days to receive needed components. To further increase speed, Dell set up a shipping arrangement with United Parcel Service (UPS). With this structure and infrastructure, Dell was able to implement its business plan.

Before You Go On

By now you should have a clear understanding of how an operations strategy is developed and its role in helping the organization decide which competitive priorities to focus on. There are four categories of competitive priorities: *cost, quality, time*, and *flexibility*. A company must make trade-offs in deciding which priorities to focus on. The operations strategy and the competitive priorities dictate the design and plan for the operations function, which includes the structure and infrastructure of the operation. This is a dynamic process, and as the environment changes, the organization must be prepared to change accordingly. Operations strategy plays a key role in an organization's ability to compete. In the next section we discuss a way to measure a company's competitive capability.

STRATEGIC ROLE OF TECHNOLOGY

NIGEL TREBLIN/Getty Images, Inc.

Over the last decade we have seen an unprecedented growth in technological capability. Technology has enabled companies to share real-time information across the globe, to improve the speed and quality of their processes, and to design products in innovative ways. Companies can use technology to help them gain an advantage over their competitors. For this reason technology has become a critical factor for companies in achieving a competitive advantage. In fact, studies have shown that companies that invest in new technologies tend to improve their financial position over those that do not. However, the technologies a company acquires should not be decided on randomly, such as following the latest fad or industry trend. Rather, the selected technology needs to support the organization's competitive priorities, as we learned in the example of FedEx. Also, technology needs to be selected to enhance the company's core competencies and add to its competitive advantage.

Types of Technologies

There are three primary types of technologies. They are differentiated based on their application, but all three areas of technology are important to operations managers. The first type is *product technology*, which is any new technology developed by a firm. An example of this would include Teflon®, the material used in no-stick fry pans. Teflon became an emerging technology in the 1970s and is currently used in numerous applications. Other examples include CDs and flat-screened monitors. Product technology is important as companies must regularly update their processes to produce the latest types of products.

A second type of technology is *process technology*. It is the technology used to improve the process of creating goods and services. Examples of this would include computer-aided design (CAD) and computer-aided manufacturing (CAM). These are technologies that use computers to assist engineers in the way they design and manufacture products. Process technologies are important to companies, as they enable tasks to be accomplished more efficiently. We will learn more about these technologies in Chapter 3.

The last type of technology is *information technology*, which enables communication, processing, and storage of information. Information technology has grown rapidly over recent years and has had a profound impact on business. Just consider the changes that have occurred due to the Internet. The Internet has enabled electronic commerce and the creation of the virtual marketplace and has linked customers and buyers. Another example of information technology is enterprise resource planning (ERP), which functions via large software programs used for planning and coordinating all resources

throughout the entire enterprise. ERP systems have enabled companies to reduce costs and improve responsiveness but are highly expensive to purchase and implement. Consequently, as with any technology, investment in ERP needs to be a strategic decision.

Technology as a Tool for Competitive Advantage

Technology can be acquired to improve processes and maintain up-to-date standards. Technology can also be used to gain a competitive advantage. For example, by acquiring technology a company can improve quality, reduce costs, and improve product delivery. This can provide an advantage over the competition and help gain market share. However, investing in technology can be costly and entails risks, such as overestimating the benefits of the technology or incurring the risk of obsolescence due to rapid new inventions.

Technology should be acquired to support the company's chosen competitive priorities, not just to follow the latest market fad. Also, technology may require the company to rethink its strategy. For example, when the Internet became available, it was generally assumed that it would replace traditional ways of doing business. This has not turned out to be the case. In fact, for many companies the Internet has enhanced traditional methods. Physical activities such as shipping, warehousing, transportation, and even physical contact must still be performed. For example, pharmacy chains such as Walgreens and CVS have found that although customers place orders over the Internet, they prefer to pick them up in person. Similarly, the airlines have discovered that an easy-to-use Web site can increase airline bookings. However, successful use of a technology such as the Internet requires companies to develop strategies that integrate the technology. As you can see, acquiring technology is an important strategic decision for companies. Operations managers must consider many factors when making a purchase decision.

PRODUCTIVITY

Sound business strategy and supporting operations strategy make an organization more competitive in the marketplace. But how does a company measure its competitiveness? One of the most common ways is by measuring productivity. In this section we will look at how to measure the productivity of each of a company's resources as well as the entire organization.

Measuring Productivity

Recall that operations management is responsible for managing the transformation of many inputs into outputs, such as goods or services. A measure of how efficiently inputs are being converted into outputs is called **productivity**. Productivity measures how well resources are used. It is computed as a ratio of outputs (goods and services) to inputs (e.g., labor and materials). The more efficiently a company uses its resources, the more productive it is:

▶ **Productivity**
A measure of how efficiently an organization converts inputs into outputs.

$$\text{Productivity} = \frac{\text{output}}{\text{input}} \tag{2-1}$$

This equation can be used to measure the productivity of one worker or many, as well as the productivity of a machine, a department, the whole firm, or even a nation. The possibilities are shown in Table 2-2.

TABLE 2-2

Productivity Measures

Total Productivity Measure	$\frac{\text{Output produced}}{\text{All inputs used}}$
Partial Productivity Measure	$\frac{\text{Output}}{\text{Labor}}$ *or* $\frac{\text{Output}}{\text{Machines}}$ *or* $\frac{\text{Output}}{\text{Materials}}$ *or* $\frac{\text{Output}}{\text{Capital}}$
Multifactor Productivity Measure	$\frac{\text{Output}}{\text{Labor + machines}}$ *or* $\frac{\text{Output}}{\text{Labor + materials}}$ *or* $\frac{\text{Output}}{\text{Labor + capital + energy}}$

▶ **Total productivity** Productivity computed as a ratio of output to all organizational inputs.

When we compute productivity for all inputs combined, such as labor, machines, and capital, we are measuring **total productivity**. For example, let's say that the weekly dollar value of a company's output, such as finished goods and work in progress, is \$10,200 and that the value of its inputs, such as labor, materials, and capital, is \$8600. The company's total weekly productivity would be computed as follows:

$$\text{Total productivity} = \frac{\text{output}}{\text{input}} = \frac{\$10{,}200}{\$8600} = 1.186$$

▶ **Partial productivity** Productivity computed as a ratio of output to only one input (e.g., labor, materials, machines).

Often it is much more useful to measure the productivity of one input variable at a time in order to identify how efficiently each is being used. When we compute productivity as the ratio of output relative to a single input, we obtain a measure of **partial productivity**, also called single-factor productivity. Following are two examples of the calculation of partial productivity:

1. A bakery oven produces 346 pastries in 4 hours. What is its productivity?

$$\text{Machine productivity} = \text{number of pastries/oven time}$$
$$= \frac{346 \text{ pastries}}{4 \text{ hours}} = 86.5 \text{ pastries/hour}$$

2. Two workers paint tables in a furniture shop. If the workers paint 22 tables in 8 hours, what is their productivity?

$$\text{Labor productivity} = \frac{22 \text{ tables}}{2 \text{ workers} \times 8 \text{ hours}} = 1.375 \text{ tables/hour}$$

Examples of select partial productivity measures are shown in Table 2-3.

▶ **Multifactor productivity** Productivity computed as a ratio of output to several, but not all, inputs.

Sometimes we need to compute productivity as the ratio of output relative to a group of inputs, such as labor and materials. This is a measure of **multifactor productivity**. For example, let's say that output is worth \$382 and labor and materials costs are \$168 and \$98, respectively. A multifactor productivity measure of our use of labor and materials would be

$$\text{Multifactor productivity} = \frac{\text{output}}{\text{labor + materials}}$$
$$= \frac{\$382}{\$168 + \$98} = 1.436$$

EXAMPLE 2.1

Computing Productivity

Long Beach Bank employs three loan officers, each working eight hours per day. Each officer processes an average of five loans per day. The bank's payroll cost for the officers is \$820 per day, and there is a daily overhead expense of \$500. The bank has just purchased new computer software that should enable each officer to process eight loans per day, although the overhead expense will increase to \$550. Evaluate the change in labor and multifactor productivity before and after implementation of the new computer software.

- **Before You Begin:** When solving productivity problems, make sure that the value of outputs and inputs is computed over the same time period, such as day, week, month, or year. Also, when evaluating a *change* in productivity, compute the productivity before and after the expected change and calculate the percentage difference.

- **Solution:**

$$\text{Labor productivity (old)} = \frac{3 \text{ officers} \times 5 \text{ loans/day}}{24 \text{ labor-hours}} = \frac{15 \text{ loans/day}}{24 \text{ labor-hours}}$$

$$= 0.625 \text{ loans per labor-hour}$$

$$\text{Labor productivity (new)} = \frac{3 \text{ officers} \times 8 \text{ loans/day}}{24 \text{ labor-hours}} = \frac{24 \text{ loans/day}}{24 \text{ labor-hours}}$$

$$= 1.00 \text{ loan per labor-hour}$$

$$\text{Multifactor productivity (old)} = \frac{15 \text{ loans/day}}{\$820/\text{day} + \$500/\text{day}} = 0.0113 \text{ loans/dollar}$$

$$\text{Multifactor productivity (new)} = \frac{24 \text{ loans/day}}{\$820/\text{day} + \$550/\text{day}} = 0.0175 \text{ loans/dollar}$$

The change in labor productivity is from 0.625 to 1.00 loans per labor-hour. This results in an increase of 1.00/0.625 = 1.6, or an increase of 60 percent. The change in multifactor productivity is from 0.0113 to 0.0175 loans per dollar. This results in an increase of 0.0175/0.0113 = 1.55, or an increase of 55 percent.

TABLE 2-3

Examples of Partial Productivity Measures

Business Type	Productivity Measure
Restaurant	$\frac{\text{Customers served}}{\text{Labor-hour}}$ or $\frac{\text{Customers served}}{\text{Square foot}}$
Hospital	$\frac{\text{Patients}}{\text{Hospital bed}}$ or $\frac{\text{Patients}}{\text{Nurse-hour}}$
Amusement park	$\frac{\text{Visitors}}{\text{Square foot}}$ or $\frac{\text{Visitors}}{\text{Attraction}}$
Cattle ranch	$\frac{\text{Cattle}}{\text{Pound of feed}}$ or $\frac{\text{Cattle}}{\text{Acre of land}}$
Garment manufacturer	$\frac{\text{Sweaters}}{\text{Pound of yarn}}$ or $\frac{\text{Sweaters}}{\text{Machine-hour}}$

Interpreting Productivity Measures

To interpret the meaning of a productivity measure, it must be compared with a similar productivity measure. For example, if one worker at a pizza shop produces 17 pizzas in

two hours, the productivity of that worker is 8.5 pizzas per hour. This number by itself does not tell us very much. However, if we compare it to the productivity of two other workers, one who produces 7.2 pizzas per hour and another 6.8 pizzas per hour, it is much more meaningful. We can see that the first worker is much more productive than the other two workers. But how do we know whether the productivity of all three workers is reasonable? What we need is a standard. In Chapter 11 we will discuss ways to set standards and how those standards can help in evaluating the performance of our workers.

It is also helpful to measure and compare productivity over time. Let's say that we want to measure the total productivity of our three pizza makers (our "labor") and we compute a labor productivity measure of 7.5 pizzas per hour. This number does not tell us much about the workers' performance. However, if we compare weekly productivity measures over time, perhaps over the last four weeks, we get much more information:

Week	1	2	3	4
Productivity (pizzas/labor-hour)	5.4	6.8	7.1	7.5

Now we see that the workers' productivity is improving over time. In fact, productivity changed from 5.4 to 7.5 pizzas per labor-hour, resulting in an increase of $7.5/5.4 = 1.39$, or an increase of 39 percent. But what if we find out that our main competitor, a pizzeria down the street, has a productivity of 9.5 pizzas per labor-hour? This productivity rate is 26.7 percent ($9.5/7.5 = 1.267$) higher than our productivity in week 4. Suddenly we know that even though our productivity is going up, it should be higher. We may have to analyze our processes and increase our productivity in order to be competitive. By comparing our productivity over time and against similar operations, we have a much better sense of how high our productivity really is.

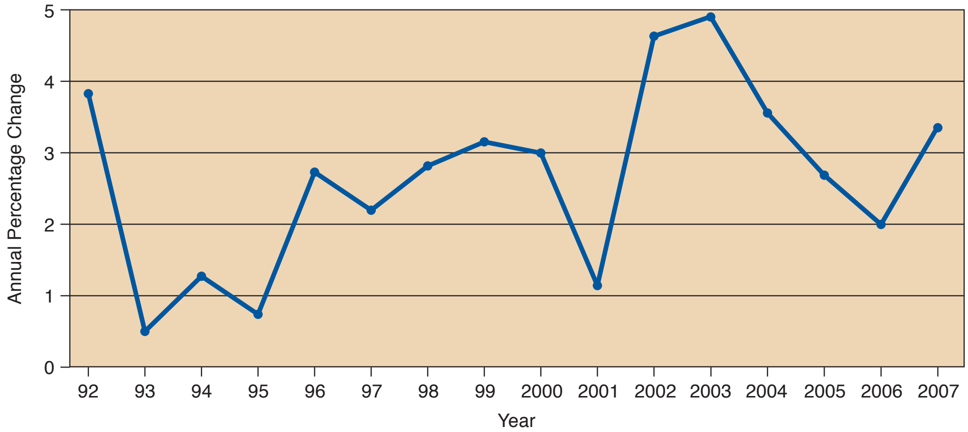
When evaluating productivity and setting standards for performance, we also need to consider our strategy for competing in the marketplace—namely, our competitive priorities. A company that competes based on speed would probably measure productivity in units produced over time. However, a company that competes based on cost might measure productivity in terms of costs of inputs such as labor, materials, and overhead. The important thing is that our productivity measure provides information on how we are doing relative to the competitive priority that is most important to us.

Productivity and Competitiveness

Productivity is essentially a scorecard of how efficiently resources are used and a measure of competitiveness. Productivity is measured on many levels and is of interest to a wide range of people. As we showed in earlier examples, productivity can be measured for individuals, departments, or organizations. It can track performance over time and help managers identify problems. Similarly, productivity can be measured for an entire industry and even a country.

The economic success of a nation and the quality of life of its citizens are related to its competitiveness in the global marketplace. Increases in productivity are directly related to increases in a nation's standard of living. That is why business and government leaders continuously monitor the productivity at the national level and by industry sectors.

Productivity in the United States had been increasing for over 100 years. Then in the 1970s and 1980s productivity dropped, even lagging behind that of other industrial nations. Fortunately, productivity rebounded in the mid- and late 1990s. Today, companies understand the importance of competitiveness, and productivity in the United States continues to improve. Changes in U.S. productivity can be seen in Figure 2-4.



Source: *Bureau of Labor Statistics*

FIGURE 2-4

Percentage change in U.S. business sector productivity (output per hour)

Productivity and the Service Sector

Service sector companies have a unique challenge when trying to measure productivity. The reason is that traditional productivity measures tend to focus on tangible outcomes, as seen with goods-producing activities. Services primarily produce intangible products, such as ideas and information, making it difficult to evaluate quality. Consequently, accurately measuring productivity improvements can be difficult. A good example of the difficulty in using traditional productivity measures in the service sector is the emergency room. Here inputs are the medical staff, yet outputs may not exist if no one needed treatment on that shift. In that case, by traditional measures, productivity would be zero! The real issue in this type of environment is the level of readiness, and the challenge is to adequately measure it.

As we discussed previously, employment in the service sector of the U.S. economy has grown rapidly over the past 30 years. Unfortunately, productivity gains in this sector have been much lower than those of manufacturing. It is hoped that advancements in information technology will help standardize services and accelerate productivity in this sector.

OPERATIONS STRATEGY WITHIN OM: HOW IT ALL FITS TOGETHER

We have learned that the strategic decisions of a firm drive its tactical decisions. Operations strategy decisions are critical in this process because they serve as a linkage between the business strategy and all the other operations decisions. Recall that operations strategy provides a plan for the OM function that supports the business strategy. In turn, decisions regarding operations strategy directly impact decisions on organizational structure and infrastructure of the company. This includes selection of the facilities (Chapter 10), type of process (Chapter 8), choice of technology (Chapter 3), quality control decisions (Chapters 5 and 6), skills and pay of workers (Chapter 11), and numerous other decisions. As in the example of Southwest Airlines, an operations strategy that focuses on cost competition would translate into specific operations decisions that eliminate all frills from the system.

In subsequent chapters of this book, we will study specific decisions that pertain to organizational structure and infrastructure. We will see that these decisions are

governed by the firm's operations strategy. We will also learn how these specific decisions impact each other.

OPERATIONS STRATEGY ACROSS THE ORGANIZATION

The business strategy defines the long-range plan for the entire company and guides the actions of each of the company's business functions. Those functions, in turn, develop plans to support the business strategy. However, in defining their individual strategies, it is important for the functions to work together and understand each other's needs.

Marketing identifies target markets, studies competition, and communicates with customers. In developing its own strategy, marketing needs to fully understand the capabilities of the operations function, the types of resources being used, and the way those resources are utilized. Otherwise, marketing's strategy could entail making promises that operations cannot deliver. In turn, marketing needs to communicate to operations all its observed and anticipated market changes.

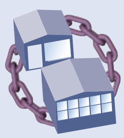
Finance develops financial plans to support the business strategy. However, since it is the operations function that manages all the organization's resources, the financial plans in effect support operations activities. Before it can develop its own strategy, finance needs to communicate with operations in order to understand the financial requirements of planned resources. In turn, operations managers cannot fully develop a strategy until they have a clear understanding of financial capabilities.

The strategies of all the business functions need to support each other in achieving the goals set by the business strategy and are best developed through a team approach.

THE SUPPLY CHAIN LINK

The operations strategy of a firm directly impacts decisions on its structure and infrastructure, including its supply chain. This includes the design of the supply chain, such as its length, and the relationships the firm has with its supply chain partners. Together, the operations strategy and the firm's supply chain must support the business strategy of the firm. This can be illustrated by the competitive priorities of the firm, which directly impact the type of supply chain a company has in place. For example, a company that competes on cost must have a highly efficient supply chain with high integration of the OM function between supply chain partners. The reason is that the supply chain plays a critical role in keeping both production and delivery costs down. Therefore, a firm competing on cost might structure its supply chain so that the least expensive suppliers are used rather than those with the highest quality supplies.

In contrast, a company that competes on quality will likely have a different supply chain. Competing on quality means that a company's products and services are known for their premium nature, such as product consistency and reliability. Many aspects of the supply chain are altered when companies compete on quality versus another competitive priority, such as cost. The company will likely source its components from suppliers known for quality who have implemented total quality management throughout their production process. The concept of quality will also be embedded in other aspects of the supply chain, such as transportation, delivery, and packaging.



An excellent example of aligning operations strategy with the supply chain is illustrated by Wal-Mart. Sam Walton, Wal-Mart's founder, was a strategic visionary who developed the low-cost retail strategy that is supported by its supply chain.

Wal-Mart's supply chain is designed to buy not from distributors but directly from manufacturers in order to lower costs and offer a broad range of merchandise. In fact, Wal-Mart has had a legendary partnership with Procter & Gamble, where replenishment of inventories is done automatically. These supply chain actions were designed to help Wal-Mart meet its overall competitive strategy, which is to provide its customers with a wide product offering at a low price. This has helped Wal-Mart become the world's largest retailer.

Chapter Highlights

1. A business strategy is a long-range plan and vision for a business. Each of the individual business functions needs to support the business strategy.
2. An organization develops its business strategy by doing environmental scanning and considering its mission and its core competencies.
3. The role of operations strategy is to provide a long-range plan for the use of the company's resources in producing the company's primary goods and services.
4. The role of business strategy is to serve as an overall guide for the development of the organization's operations strategy.
5. The operations strategy focuses on developing specific capabilities called competitive priorities. In designing its operation, an organization is governed by the operations strategy and the specific competitive priorities it has chosen to develop.
6. There are four categories of competitive priorities: cost, quality, time, and flexibility.
7. Technology can be used by companies to gain a competitive advantage and should be acquired to support the company's chosen competitive priorities.
8. Productivity is a measure that indicates how efficiently an organization is using its resources.
9. Productivity is computed as the ratio of organizational outputs divided by inputs.

Key Terms

business strategy 29
operations strategy 29
mission 31
environmental scanning 32
core competencies 34
competitive priorities 36
cost 36
quality 38
time 38
flexibility 39
trade-off 40
order qualifiers 40
order winners 40
structure 41
infrastructure 41
productivity 43
total productivity 44
partial productivity 44
multifactor productivity 44

Formula Review

$$\text{Productivity} = \frac{\text{output}}{\text{input}}$$

Solved Problems

(See student companion site for Excel template.)

• Problem 1

Bluegill Furniture is a small furniture shop that focuses on making kitchen chairs. The weekly dollar value of its output, including finished goods and work in progress, is $14,280. The value of inputs, such as labor, materials, and capital, is approximately $16,528. Compute the total productivity measure for Bluegill Furniture.

• *Before You Begin:*

In this problem you are being asked for the total productivity. Recall that it is simply the ratio of total output over input.

• *Solution*

$$\text{Total productivity} = \frac{\text{output}}{\text{input}} = \frac{\$14{,}280}{\$16{,}528} = 0.864$$

• Problem 2

Bluegill has just purchased a new sanding machine that processes 17 chairs in 8 hours. What is the productivity of the sanding machine?

• *Before You Begin:*

In this problem you are being asked for machine productivity, which is a partial productivity measure.

• *Solution*

$$\text{Machine productivity} = \frac{\text{number of chairs}}{\text{processing time}}$$

$$= \frac{17 \text{ chairs}}{8 \text{ hours}}$$

$$= 2.125 \text{ chairs/hour}$$

• Problem 3

Bluegill has hired two new workers to paint chairs. They have painted 10 chairs in 4 hours. What is their labor productivity?

• Before You Begin:

Remember that you should compute the labor productivity of both workers combined.

• Solution

$$\text{Labor productivity} = \frac{10 \text{ chairs}}{2 \text{ workers} \times 4 \text{ hours}}$$

$$= 1.25 \text{ chairs/hour}$$

• Problem 4

On average, Bluegill produces 35 chairs per day. Labor costs average $480, material costs are typically $200, and overhead cost is $250. If Bluegill sells the chairs to a retailer for $70 each, determine the multifactor productivity.

• Before You Begin:

When computing multifactor productivity, remember to compute the total value of the inputs before taking the ratio.

• Solution

$$\text{Multifactor productivity} = \frac{\text{value of output}}{\text{labor costs} + \text{material cost} + \text{overhead}}$$

$$= \frac{35 \text{ chairs} \times \$70/\text{chair}}{\$480 + \$200 + \$250}$$

$$= \frac{\$2450}{\$930}$$

$$= \$2.63 \text{ of sales per dollar}$$

• Problem 5

Last week employees at Bluegill produced 46 chairs after working a total of 200 hours. Of the 46 chairs produced, 12 were damaged due to a problem with the new sanding machine. The damaged chairs can be discounted and sold for $25 each. The undamaged chairs are sold to a department store retail chain for $70 each. What was the labor productivity ratio for last week? If labor productivity was $15 in sales per hour the previous week, what was the change in labor productivity?

• Before You Begin:

To compute productivity you must include the total value of the output. Notice that in this problem there are different quantities of products that have different values (damaged and good chairs). You must compute the value of each type of chair and add them together to obtain the total value before taking the ratio.

• Solution

$$\text{Value to output} = (12 \text{ damaged chairs} \times \$25/\text{damaged chair}) + (34 \text{ good chairs} \times \$70/\text{good chair})$$

$$= \$2680$$

$$\text{Labor-hours of input} = 200 \text{ hours}$$

$$\text{Labor productivity} = \frac{\text{value of output}}{\text{labor-hours of input}}$$

$$\text{Labor productivity} = \frac{\$2680}{200 \text{ hours}}$$

$$= \$13.40 \text{ in sales per hour}$$

The change in labor productivity was from $15 to $13.40 in sales per hour, or a reduction of 10.67 percent.

Discussion Questions

1. Explain the importance of a business strategy.
2. Explain the role of operations strategy in a business.
3. Describe how a business strategy is developed.
4. Describe how an operations strategy is formulated from the business strategy.
5. Explain what is meant by the term *competitive priority* and describe the four categories of competitive priorities discussed in the chapter.
6. Find an example of a company that makes quality its competitive priority. Find another company that makes flexibility its competitive priority. Compare these strategies.
7. What is meant by the terms *order qualifiers* and *order winners*? Explain why they are important.
8. Describe the three types of technologies. Explain the strategic role of technology.
9. Describe the meaning of productivity. Why is it important?
10. Explain the three types of productivity measures.

Problems

1. Two workers have the job of placing plastic labels on packages before the packages are shipped out. The first worker can place 1000 labels in 30 minutes. The second worker can place 850 labels in 20 minutes. Which worker is more productive?

2. Last week a painter painted three houses in five days. This week she painted two houses in four days. In which week was the painter more productive?

3. One type of bread-making machine can make six loaves of bread in five hours. A new model of the machine can make four loaves in two hours. Which model is more productive?

4. A company that makes kitchen chairs wants to compare productivity at two of its facilities. At facility #1, six workers produced 240 chairs. At facility #2, four workers produced 210 chairs during the same time period. Which facility was more productive?

5. A painter is considering using a new high-tech paint roller. Yesterday he was able to paint three walls in 45 minutes using his old method. Today he painted two walls of the same size in 20 minutes. Is the painter more productive using the new paint roller?

6. Aztec Furnishings makes hand-crafted furniture for sale in its retail stores. The furniture maker has recently installed a new assembly process, including a new sander and polisher. With this new system, production has increased to 90 pieces of furniture per day from the previous 60 pieces of furniture per day. The number of defective items produced has dropped from 10 pieces per day to 1 per day. The production facility operates strictly eight hours per day. Evaluate the change in productivity for Aztec using the new assembly process.

7. Howard Plastics produces plastic containers for use in the food packaging industry. Last year its average monthly production included 20,000 containers produced using one shift five days a week with an eight-hour-a-day operation. Of the items produced 15 percent were deemed defective. Recently, Howard Plastics has implemented new production methods and a new quality improvement program. Its monthly production has increased to 25,000 containers with 9 percent defective.

(a) Compute productivity ratios for the old and new production system.

(b) Compare the changes in productivity between the two production systems.

8. Med-Tech labs is a facility that provides medical tests and evaluations for patients, ranging from analyzing blood samples to performing magnetic resonance imaging (MRI). Average cost to patients is $60 per patient. Labor costs average $15 per patient, materials costs are $20 per patient, and overhead costs are averaged at $20 per patient.

(a) What is the *multifactor* productivity ratio for Med-Tech? What does your finding mean?

(b) If the average lab worker spends three hours for each patient, what is the *labor* productivity ratio?

9. Handy-Maid Cleaning Service operates five crews with three workers per crew. Different crews clean a different number of homes per week and spend a differing amount of hours. All the homes cleaned are about the same size. The manager of Handy-Maid is trying to evaluate the productivity of each of the crews. The following data have been collected over the past week.

Work Crew	Hours	Homes Cleaned
Anna, Sue, and Tim	35	10
Jim, Jose, and Andy	45	15
Dan, Wendy, and Carry	56	18
Rosie, Chandra, and Seth	30	10
Sherry, Vicky, and Roger	42	18

Assuming the quality of cleaning was consistent between crews, which crew was most productive?

CASE: Prime Bank of Massachusetts

Prime Bank of Massachusetts was started in 1964 with James Rogers as CEO, who is now chairman of the board. Prime Bank had been growing steadily since its beginning and has developed a loyal customer following. Today there are 45 bank locations throughout Massachusetts, with corporate headquarters in Newbury, Massachusetts. The bank offers a wide array of banking services to commercial and noncommercial customers.

Prime Bank has considered itself to be a conservative, yet innovative, organization. Its locations are open Monday–Friday 9–4 and Saturday 9–12. Most of the facilities are located adjacent to well-established shopping centers, with multiple ATM machines and at least three drive-through windows. However, Prime Bank's growth has brought on certain problems. Having the right amount of tellers available in the bank as well as in the drive-through window has been a challenge. Some commercial customers had recently expressed frustration due to long waiting time. Also, the parking lot has often become crowded during peak periods.

While Prime Bank was going through a growth period, the general banking industry had been experiencing tougher competition. Competitors were increasingly offering lower interest rates on loans and higher yields on savings accounts and certificates of deposit. Also, Prime Bank was experiencing growing pains, and something needed to be done soon or it would begin losing customers to competition.

The board, headed by James Rogers, decided to develop a more aggressive strategy for Prime Bank. While many of its competitors were competing on *cost*, the board decided that Prime Bank should focus on *customer service* in order to differentiate itself from the competition. The bank had already begun moving in that direction by offering a 24-hour customer service department to answer customers' banking questions. Yet, there were difficulties with this effort, such as poor staffing and not enough telephone lines. James Rogers wanted Prime Bank to aggressively solve all customer service issues, such as staffing, layout, and facilities. He also wanted greater creativity in adding improvements in customer service, such as on-line banking, and special services for large customers. He believed that improving most aspects of the bank's operation would give Prime Bank a competitive advantage.

The board presented their new strategy to Victoria Chen, vice president of operations. Victoria had recently been promoted to the V.P. level and understood the importance of operations management. She was asked to identify all changes that should be made in the operation function that would

support this new strategy and present them at the next board meeting. Victoria had been hoping for an opportunity to prove herself since she began with the bank. This was her chance.

Case Questions

1. Why is the operations function important in implementing the strategy of an organization? Explain why the changes put in place by Victoria Chen and her team could either hurt or help the bank.

2. Develop a list of changes for the operations function that should be considered by the bank. Begin by identifying operations management decisions that would be involved in operating a bank, for example, layout of facility, staff, drive-through service. Then identify ways that they can be improved at Prime Bank in order to support the strategy focused on customer service.

3. Think of the improvements identified in answering question 2. How different would these improvements be if the bank had a strategy of cutting cost rather than supporting customer service?

CASE: Boseman Oil and Petroleum (BOP)

Boseman Oil and Petroleum (BOP) is one of many oil companies operating offshore petroleum platforms in the Gulf of Mexico. The company identifies offshore sites for exploration drilling and constructs drilling platforms. Once exploration activities are successful, the platforms are converted to a production platform to extract crude oil and natural gas. BOP operates multiple platforms and an onshore facility that serves as the primary interface between the platforms. Boats with specialized crews provide logistics services between the platforms and the onshore facility. The boats deliver fuel, water, equipment, and other needed supplies multiple times a day to the platforms. Accurate and timely delivery of materials is absolutely necessary for successful platform operations.

BOP had traditionally focused on exploration and production activities, paying little attention to operating costs. However, operating costs had been increasing rapidly. A particularly significant cost was the operating of boats and crews needed to provide logistics services between platforms and the onshore facility. The boats are highly specialized, with built-in storage tanks and unique cargo space designs. The boat crews are specially trained, and operating the boats and crews is highly expensive. Although BOP is dependent on the boat deliveries, it does not use the boats at full capacity and they are often idle.

Jeff Kessinger, director of offshore operations for BOP, is now faced with the decision of how to reduce operating costs. One option is to outsource the logistics service to a company specializing in providing offshore logistics services. Logistics-Offshore Inc. is such a company, owning and maintaining its own fleet of boats and crews. Logistics-Offshore could be hired to perform this function. BOP could sell its boats and focus on oil exploration. Jeff is aware that outsourcing is an important strategic decision and there is much to consider. He is not sure where to begin.

Case Questions

1. Identify the potential strategic advantages and disadvantages for BOP in outsourcing the boat logistics service to Logistics-Offshore. Explain the strategic implications of each.

2. Identify the type of information Jeff Kessinger needs to gather and evaluate in order to make his decision.

INTERACTIVE CASE Virtual Company

www.wiley.com/college/reid

On-line Case: Cruise International, Inc.

Assignment: *Getting Acquainted with Cruise International, Inc.* After a few minutes on hold, you hear Bob Bristol begin speaking on the phone. "Hello," he begins. "I understand that you wanted to let me know about your progress and needed some additional guidelines. My assistant, Shontelle, gave me the details of your work on the first assignment. I am pleased that you are beginning to learn about CII and the cruising industry. Since you still have some time before starting at CII, I think it would be a good idea for you to get some broad insights into the industry and its competitive environment.

"You must look at the big picture and try to understand the company's vision and its mission. I want to identify the core vales that CII emphasizes and explain how a specific emphasis dictates its business practices." This assignment will enhance your knowledge of the material in Chapter 2 of your textbook while preparing you for future assignments.

To access the Web site:

- Go to **www.wiley.com/college/reid**
- Click **Student Companion Site**
- Click **Virtual Company**
- Click **Consulting Assignments**
- Click **Getting Acquainted with Cruise International, Inc.**

INTERNET CHALLENGE Understanding Strategic Differences

Select two companies in the same industry, either in service or in manufacturing. You can select industries such as fast-food, banking, healthcare, computer manufacturing, or auto manufacturing. Use the Internet to visit the selected companies' Web sites and collect the following information: their mission statement, target market, and specifics of their product and service offerings. Explain the differences between the companies' business strategies and target markets. How do their product and service offerings differ relative to their target markets and their overall strategies? Finally, how does their operations function support their business strategies? Try to explain how operations utilizes specific organizational resources to support the business strategy.

Web sites to consider:

www.lhcargo.com (Lufthansa Cargo)
www.ualcargo.com (United Airlines, United Cargo)

On-line Resources

Companion Website www.wiley.com/college/reid

- Take interactive *practice quizzes* to assess your knowledge and help you study in a dynamic way
- Review *PowerPoint slides* or print slides for notetaking
- Access the *Virtual Company: Cruise International, Inc.*
- Find links to *Company Tours* for this chapter
  The Boeing Company
  Sensenich Propeller Manufacturing Company
- Find links for *Additional Web Resources* for this chapter
  The Association for Manufacturing Excellence, *www.ame.org*

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CHAPTER 3

Product Design and Process Selection

Before studying this chapter you should know or, if necessary, review

1. Differences between manufacturing and service organizations, Chapter 1, pp. 5–7.
2. Differences between strategic and tactical decisions, Chapter 1, pp. 7–10.
3. Competitive priorities, Chapter 2, pp. 36–42.

LEARNING OBJECTIVES

After completing this chapter you should be able to

1. Define product design and explain its strategic impact on the organization.
2. Describe the steps used to develop a product design.
3. Use break-even analysis as a tool in deciding between alternative products.
4. Identify different types of processes and explain their characteristics.
5. Understand how to use a process flowchart.
6. Understand how to use process performance metrics.
7. Understand current technological advancements and how they impact process and product design.
8. Understand issues of designing service operations.

CHAPTER OUTLINE

WHAT'S IN OM FOR ME?

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Have you ever been with a group of friends and decided to order pizzas? One person wants pizza from Pizza Hut because he likes the taste of stuffed-crust pizza made with cheese in the crust. Someone else wants Donatos pizza because she likes the unique crispy-thin crust. A third wants pizza from Spagio's because of the wood-grilled oven taste. Even a simple product like a pizza can have different features unique to its producer. Different customers have different tastes, preferences, and product needs. The variety of product designs on the market appeals to the preferences of a particular customer group. Also, the different product designs have different processing requirements. This is what product design and process selection are all about.

Burke/Triolo Productions/Foodpix/Jupiter Images Corp.

We can all relate to the product design of a pizza just from everyday life. Now consider the complexities involved in designing more sophisticated products. For example, Palm, Inc. (www.palm.com) is a leading provider of handheld computers whose slogan is "different people, different needs, different handhelds." The company designs different products with differing capabilities, such as personal information management, wireless Internet access, and games, intended for different types of customers. The company also has to decide on the best process to produce the different types of handhelds.

The challenge of product design can also be illustrated by an example from the Alza Corporation. Alza is a leader in designing new ways that pharmaceutical drugs can be administered to different types of patients. One of their product designs is an under-the-skin implant for pharmaceutical drugs that previously could only be administered by injection. The product design had to include time release of the drug, as well as the best material and shape for the implant. In addition to the product design, a process had to be designed to produce the unique product.

These examples illustrate that a product design that meets customer needs, although challenging, can have a large impact on a company's success. In fact, product design is so important that leading-edge companies routinely invest in product designs well into the future. For example, in 2009 Sony released cameras that include intelligent auto mode that give users picture-perfect shots without fumbling with settings. This type of innovative product design can give a company a significant competitive advantage.

In this chapter we will learn about *product design*, which is the process of deciding on the unique characteristics and features of the company's product. We will also learn about *process selection*, which is the development of the process necessary to produce the designed product. Product design and process selection decisions are typically made together. A company can have a highly innovative design for its product, but if it has not determined how to make the product in a cost-effective way, the product will stay a design forever.

Product design and process selection affect product quality, product cost, and customer satisfaction. If the product is not well designed or if the manufacturing process is not true to the product design, the quality of the product may suffer. Furthermore, the product has to be manufactured using materials, equipment, and labor skills that are efficient and affordable; otherwise, its cost will be too high for the market. We call this the product's **manufacturability**—the ease with which the product can be made. Finally, if a product is to achieve customer satisfaction, it must have the combined characteristics of good design, competitive pricing, and the ability to fill a market need. This is true whether the product is pizzas or cars.

▶ **Manufacturability**
The ease with which a product can be made.

PRODUCT DESIGN

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Most of us might think that the design of a product is not that interesting. After all, it probably involves materials, measurements, dimensions, and blueprints. When we think of design, we usually think of car design or computer design and envision engineers working on diagrams. However, product design is much more than that. Product design brings together marketing analysts, art directors, sales forecasters, engineers, finance experts, and other members of a company to think and plan strategically. It is exciting and creative, and it can spell success or disaster for a company.

Product design is the process of defining all the features and characteristics of just about anything you can think of, from Starbucks' cafe latte or Jimmy Dean's sausage to GM's Saturn or HP's DeskJet printer. Product design also includes the design of services, such as those provided by Salazar's Beauty Salon, La Petite Academy Day Care Center, or FedEx. Consumers respond to a product's appearance, color, texture, and performance. All of its features, summed up, are the product's design. Someone came up with the idea of what this product will look like, taste like, or feel like so that it will appeal to you. This is the purpose of product design. **Product design** defines a product's characteristics, such as its appearance, the materials it is made of, its dimensions and tolerances, and its performance standards.

▶ **Product design**
The process of defining all of the product's characteristics.

Kiyoshi Ota/Getty Images, Inc.

Product design of cell phones combines portability, features, and aesthetics.

Design of Services versus Goods

The design elements discussed are typical of industries such as manufacturing and retail in which the product is tangible. For service industries, where the product is intangible, the design elements are equally important, but they have an added dimension.

Service design is unique in that both the service and the entire *service concept* are being designed. As with a tangible product, the service concept is based on meeting customer needs. The service design, however, adds the aesthetic and psychological benefits of the product. These are the service elements of the operation, such as promptness and friendliness. They also include the ambiance, image, and "feel-good" elements of the service. Consider the differences in service design of a company like Canyon Ranch, which provides a pampering retreat for health-conscious

but overworked professionals, versus Gold's Gym, which caters to young athletes. As with a tangible product, the preference for a service is based on its product design. **Service design** defines the characteristics of a service, such as its physical elements, and the aesthetic and psychological benefits it provides.

▶ **Service design**
The process of establishing all the characteristics of the service, including physical, sensual, and psychological benefits.

THE PRODUCT DESIGN PROCESS

Certain steps are common to the development of most product designs: idea generation, product screening, preliminary design and testing, and final design. These steps are shown in Figure 3-1. Notice that the arrows show a circular process. Product designs are never finished, but are always updated with new ideas. Let's look at these steps in more detail.

Idea Development

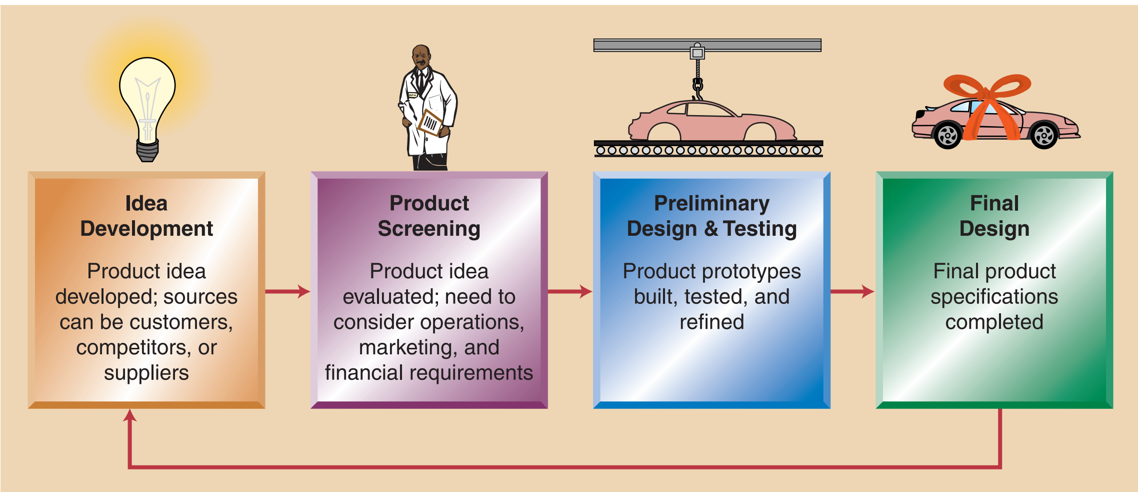
All product designs begin with an idea. The idea might come from a product manager who spends time with customers and has a sense of what customers want, from an engineer with a flare for inventions, or from anyone else in the company. To remain competitive, companies must be innovative and bring out new products regularly. In some industries, the cycle of new product development is predictable. We see this in the auto industry, where new car models come out every year, or the retail industry, where new fashion is designed for every season.

In other industries, new product releases are less predictable but just as important. The Body Shop, retailer of plant-based skin care products, periodically comes up with new ideas for its product lines. The timing often has to do with the market for a product and whether sales are declining or continuing to grow.

Ideas from Customers, Competitors, and Suppliers The first source of ideas is customers, the driving force in the design of goods and services. Marketing is a vital link between customers and product design. Market researchers collect customer

FIGURE 3-1

Steps in the product design process



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information by studying customer buying patterns and using tools such as customer surveys and focus groups. Management may love an idea, but if market analysis shows that customers do not like it, the idea is not viable. Analyzing customer preferences is an ongoing process; customer preferences next year may be quite different from what they are today. For this reason, the related process of forecasting future consumer preferences is important, though difficult.

Competitors are another source of ideas. A company learns by observing its competitors' products and their success rate. This includes looking at product design, pricing strategy, and other aspects of the operation. Studying the practices of companies considered "best-in-class" and comparing the performance of one's own company against theirs is called **benchmarking**. We can benchmark against a company in a completely different line of business and still learn from some aspect of that company's operation. For example, Lands' End is well known for its successful catalog business, and companies considering catalog sales often benchmark against Lands' End. Similarly, American Express is a company known for its success at resolving complaints, and it, too, is used for benchmarking.

▶ **Benchmarking**
The process of studying the practices of companies considered "best-in-class" and comparing your company's performance against theirs.

LINKS TO PRACTICE

IBM Corporation
www.ibm.com

Joern Pollex/Getty Images, Inc.

The importance of benchmarking can be seen by IBM's efforts to improve its distribution system. In 1997, IBM found its distribution costs increasing while customers were expecting decreasing times from factory to delivery. It appeared that IBM's supply chain practices were not keeping up with those of its competitors. To evaluate and solve this problem, IBM hired Mercer Management Consultants, who performed a large benchmarking study. IBM's practices were compared to those of market leaders in the personal computer (PC) industry, as well as to the best logistics practices outside the technology area. The objective was to evaluate IBM's current performance, that of companies considered best-in-class, and identify the gaps. Through the study, IBM discovered which specific costs exceeded industry benchmarks and which parts of the cycle time were excessively long. It also uncovered ways to simplify and reorganize its processes to gain efficiency. Based on findings from the benchmarking effort, IBM made changes in its operations. The results were reduced costs, improved delivery, and improved relationships with suppliers. IBM found benchmarking so beneficial that it plans to perform similar types of studies on an ongoing basis in the future.

Reverse Engineering Another way of using competitors' ideas is to buy a competitor's new product and study its design features. Using a process called **reverse engineering**, a company's engineers carefully disassemble the product and analyze its parts and features. Ford Motor Company used this approach to design its Taurus model. Ford engineers disassembled and studied many other car models, such as BMW and Toyota, and adapted and combined their best features. Product design ideas are also generated by a company's R & D (research and development) department, whose role is to develop product and process innovation.

▶ **Reverse engineering**
The process of disassembling a product to analyze its design features.

Suppliers are another source of product design ideas. To remain competitive, more companies are developing partnering relationships with their suppliers to jointly sat-

isfy the end customer. Suppliers participate in a program called **early supplier involvement** (**ESI**), which involves them in the early stages of product design.

▶ **Early supplier involvement (ESI)**
Involving suppliers in the early stages of product design.

Product Screening

After a product idea has been developed, it is evaluated to determine its likelihood of success. This is called *product screening*. The company's product screening team evaluates the product design idea according to the needs of the major business functions. In their evaluation, executives from each function area may explore issues such as the following:

- **Operations** What are the production needs of the proposed new product, and how do they match our existing resources? Will we need new facilities and equipment? Do we have the labor skills to make the product? Can the material for production be readily obtained?
- **Marketing** What is the potential size of the market for the proposed new product? How much effort will be needed to develop a market for the product, and what is the long-term product potential?
- **Finance** The production of a new product is a financial investment like any other. What is the proposed new product's financial potential, cost, and return on investment?

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Unfortunately, there is no magic formula for deciding whether or not to pursue a particular product idea. Managerial skill and experience, however, are key. Companies generate new product ideas all the time, whether for a new brand of cereal or a new design for a car door. Approximately 80 percent of ideas do not make it past the screening stage. Management analyzes operations, marketing, and financial factors and then makes the final decision. Fortunately, we have decision-making tools to help us evaluate new product ideas. A popular one is break-even analysis, which we look at next.

Break-Even Analysis: A Tool for Product Screening

Break-even analysis is a technique that can be useful when evaluating a new product. It computes the quantity of goods a company needs to sell just to cover its costs, or break even, called the "break-even" point. When evaluating an idea for a new product, it is helpful to compute its break-even quantity. An assessment can then be made as to how difficult or easy it will be to cover costs and make a profit. A product with a break-even quantity that is hard to attain might not be a good product choice to pursue. Next we look at how to compute the break-even quantity.

▶ **Break-even analysis**
A technique used to compute the amount of goods a company would need to sell to cover its costs.

The total cost of producing a product or service is the sum of its fixed and variable costs. A company incurs **fixed costs** regardless of how much it produces. Fixed costs include overhead, taxes, and insurance. For example, a company must pay for overhead even if it produces nothing. **Variable costs**, on the other hand, are costs that vary directly with the amount of units produced and include items such as direct materials and labor. Together, fixed and variable costs add up to total cost:

▶ **Fixed costs**
Costs a company incurs regardless of how much it produces.

▶ **Variable costs**
Costs that vary directly with the amount of units produced.

$$\text{Total cost} = F + (VC)Q$$

where F = fixed cost
VC = variable cost per unit
Q = number of units sold

Figure 3-2 shows a graphical representation of these costs as well as the break-even quantity. Fixed cost is represented by a horizontal line as this cost is the same regardless of how much is produced. Adding variable cost to fixed cost creates *total cost*, represented by the diagonal line above fixed cost. When $Q = 0$, total cost is only equal to fixed cost. As Q increases, total cost increases through the variable cost component. The blue diagonal in the figure is revenue, the amount of money brought in from sales:

$$\text{Revenue } (SP)Q$$

where SP = selling price per unit

When $Q = 0$, revenue is zero. As sales increase, so does revenue. Remember, however, that to cover all costs we have to sell the break-even amount. This is the quantity Q_{BE}, where revenue equals total cost. If we sell below the break-even point, we incur a loss, since costs exceed revenue. To make a profit, we have to sell above the break-even point. Since revenue equals total cost at the break-even point, we can use the previous equations to compute the value of the break-even quantity:

$$\text{Total cost} = \text{total revenue}$$

$$F + (VC)Q = (SP)Q$$

Solving for Q, we get the following equation:

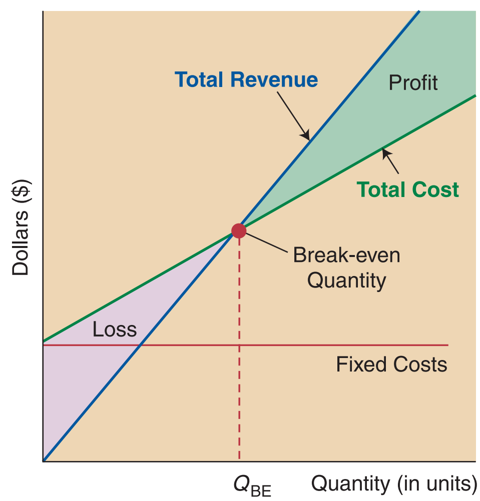
$$Q_{BE} = \frac{F}{SP - VC}$$

Note that we could also find the break-even point by drawing the graph and finding where the total cost and revenue lines cross.

Break-even analysis is useful for more than just deciding between different products. It can be used to make other decisions, such as evaluating different processes or deciding whether the company should make or buy a product.

FIGURE 3-2

Graphical approach to break-even analysis



EXAMPLE 3.1

Computing the Break-even Quantity

Fred Boulder, owner of Sports Feet Manufacturing, is considering whether to produce a new line of footwear. Fred has considered the processing needs for the new product as well as the market potential. He has also estimated that the variable cost for each product manufactured and sold is \$9 and the fixed cost per year is \$52,000.

(a) If Fred offers the footwear at a selling price of \$25, how many pairs must he sell to break even?
(b) If Fred sells 4000 pairs at the \$25 price, what will be the contribution to profit?

• Solution:

(a) To compute the break-even quantity:

$$Q = \frac{F}{SP - VC}$$

$$= \frac{\$52{,}000}{\$25 - \$9} = 3250 \text{ pairs}$$

The break-even quantity is 3250 pairs. This is how much Fred would have to sell to cover costs.

(b) To compute the contribution to profit with sales of 4000 pairs, we can go back to the relationship between cost and revenue:

$$\text{Profit} = \text{total revenue} - \text{total cost}$$

$$= (SP)Q - [F + (VC)Q]$$

$$\text{Profit} = \$25(4000) - [\$52{,}000 + \$9(4000)]$$

$$= \$12{,}000$$

The contribution to profit is \$12,000 if Fred can sell 4000 pairs from his new line of footwear.

Preliminary Design and Testing

Once a product idea has passed the screening stage, it is time to begin preliminary design and testing. At this stage design engineers translate general performance specifications into technical specifications. Prototypes are built and tested. Changes are made based on test results, and the process of revising, rebuilding a prototype, and testing continues. For service companies this may entail testing the offering on a small scale and working with customers to refine the service offering. Fast-food restaurants are known for this type of testing, where a new menu item may be tested in only one particular geographic area. Product refinement can be time-consuming, and the company may want to hurry through this phase to rush the product to market. However, rushing creates the risk that all the "bugs" have not been worked out, which can prove very costly.

Final Design

Following extensive design testing, the product moves to the final design stage. This is where final product specifications are drawn up. The final specifications are then translated into specific processing instructions to manufacture the product, which include selecting equipment, outlining jobs that need to be performed, identifying specific materials needed and suppliers that will be used, and all the other aspects of organizing the process of product production.

TABLE 3-1

Guidelines for DFM

DFM Guidelines
1. Minimize parts.
2. Design parts for different products.
3. Use modular design.
4. Avoid tools.
5. Simplify operations.

FACTORS IMPACTING PRODUCT DESIGN

Here are some additional factors that need to be considered during the product design stage.

Design for Manufacture

When we think of product design, we generally first think of how to please the customer. However, we also need to consider how easy or difficult it is to manufacture the product. Otherwise, we might have a great idea that is difficult or too costly to manufacture. **Design for manufacture** (**DFM**) is a series of guidelines that we should follow to produce a product easily and profitably. DFM guidelines focus on two issues:

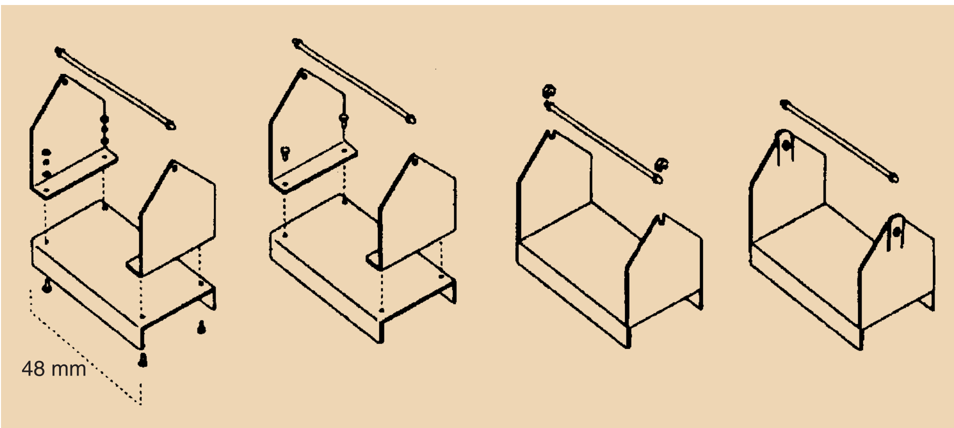
▶ **Design for manufacture (DFM)**
A series of guidelines to follow in order to produce a product easily and profitably.

1. *Design simplification* means reducing the number of parts and features of the product whenever possible. A simpler product is easier to make, costs less, and gives higher quality.
2. *Design standardization* refers to the use of common and interchangeable parts. By using interchangeable parts, we can make a greater variety of products with less inventory and significantly lower cost and provide greater flexibility. Table 3-1 shows guidelines for DFM.

An example of the benefits of applying these rules is seen in Figure 3-3. We can see the progression in the design of a toolbox using the DFM approach. All of the pictures

FIGURE 3-3

Progressive design of a toolbox using DFM



show a toolbox. However, the first design shown requires 20 parts. Through simplification and use of modular design, the number of parts required has been reduced to 2. It would certainly be much easier to make the product with 2 parts versus 20 parts. This means fewer chances for error, better quality, and lower costs due to shorter assembly time.

Product Life Cycle

Another factor in product design is the stage of the life cycle of the product. Most products go through a series of stages of changing product demand called the **product life cycle**. There are typically four stages of the product life cycle: introduction, growth, maturity, and decline. These are shown in Figure 3-4.

▶ **Product life cycle**
A series of stages that products pass through in their lifetime, characterized by changing product demands over time.

Products in the introductory stage are not well defined, and neither is their market. Often all the "bugs" have not been worked out, and customers are uncertain about the product. In the growth stage, the product takes hold and both product and market continue to be refined. The third stage is that of maturity, where demand levels off and there are usually no design changes: the product is predictable at this stage and so is its market. Many products, such as toothpaste, can stay in this stage for many years. Finally, there is a decline in demand because of new technology, better product design, or market saturation.

The first two stages of the life cycle can collectively be called the early stages because the product is still being improved and refined and the market is still in the process of being developed. The last two stages of the life cycle can be referred to as the later stages because here both the product and market are well defined.

Understanding the stages of the product life cycle is important for product design purposes, such as knowing at which stage to focus on design changes. Also, when considering a new product, the expected length of the life cycle is critical in order to estimate future profitability relative to the initial investment. The product life cycle can be quite short for certain products, as seen in the computer industry. For other products it can be extremely long, as in the aircraft industry. A few products, such as paper, pencils, nails, milk, sugar, and flour, do not go through a life cycle. However, almost all products do, and some may spend a long time in one stage.

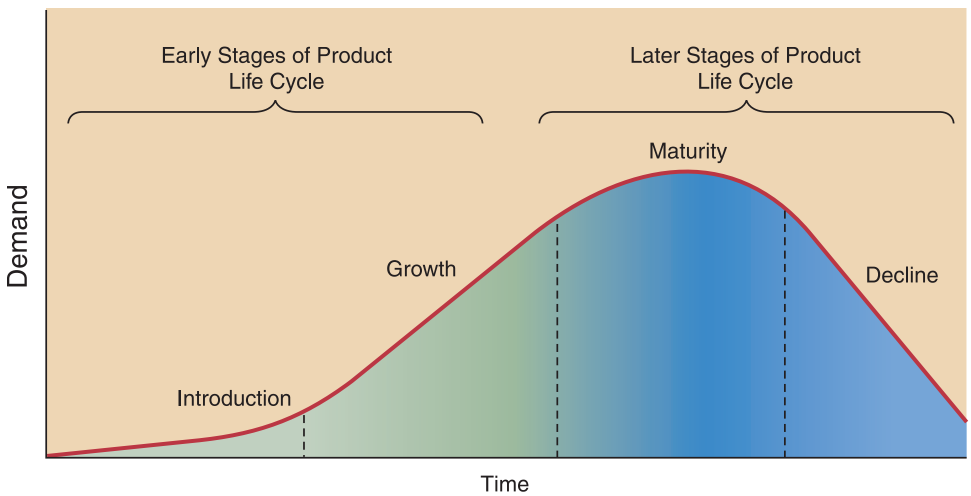


FIGURE 3-4

Stages of the product life cycle

Concurrent Engineering

► **Concurrent engineering** An approach that brings together multifunction teams in the early phase of product design in order to simultaneously design the product and the process.

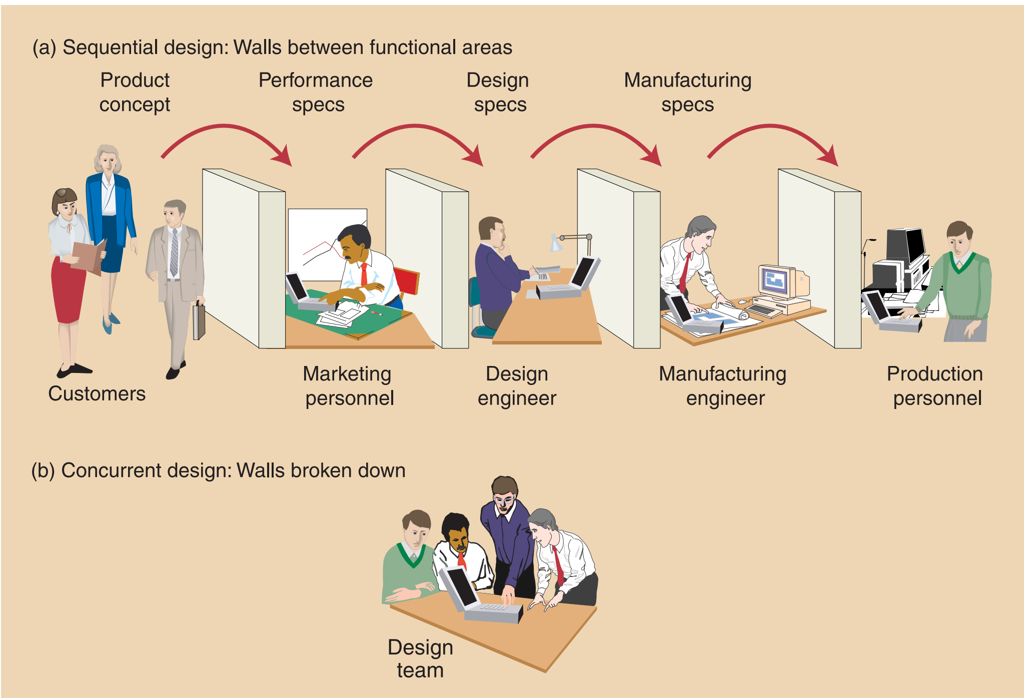
Concurrent engineering is an approach that brings many people together in the early phase of product design in order to simultaneously design the product and the process. This type of approach has been found to achieve a smooth transition from the design stage to actual production in a shorter amount of development time with improved quality results.

The old approach to product and process design was to first have the designers of the idea come up with the exact product characteristics. Once their design was complete they would pass it on to operations, who would then design the production process needed to produce the product. This was called the "over-the-wall" approach because the designers would throw their design "over-the-wall" to operations, who then had to decide how to produce the product.

There are many problems with the old approach. First, it is very inefficient and costly. For example, there may be certain aspects of the product that are not critical for product success but are costly or difficult to manufacture, such as a dye color that is difficult to achieve. Since manufacturing does not understand which features are not critical, it may develop an unnecessarily costly production process with costs passed down to the customers. Because the designers do not know the cost of the added feature, they may not have the opportunity to change their design or may do so much later in the process, incurring additional costs. Concurrent engineering allows everyone to work together so these problems do not occur. Figure 3-5 shows the difference between the "over-the-wall" approach and concurrent engineering.

FIGURE 3-5

The first illustration shows sequential design with walls between functional areas. The second illustration shows concurrent design with walls broken down.



A second problem is that the "over-the-wall" approach takes a longer amount of time than when product and process design are performed concurrently. As you can see in Figure 3-5, when product and process design are done together, much of the work is done in parallel rather than in sequence. In today's markets, new product introductions are expected to occur faster than ever. Companies do not have the luxury of enough time to follow a sequential approach and then work the "bugs" out. They may eventually get a great product, but by then the market may not be there!

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The third problem is that the old approach does not create a team atmosphere, which is important in today's work environment. Rather, it creates an atmosphere where each function views its role separately in a type of "us versus them" mentality. With the old approach, when the designers were finished with the designs, they considered their job done. If there were problems, each group blamed the other. With concurrent engineering, the team is responsible for designing and getting the product to market. Team members continue working together to resolve problems with the product and improve the process.

Remanufacturing

Remanufacturing is a concept that has been gaining increasing importance as our society becomes more environmentally conscious and focuses on recycling and eliminating waste. **Remanufacturing** uses components of old products in the production of new ones. In addition to the environmental benefits, there are significant cost benefits because remanufactured products can be half the price of their new counterparts. Remanufacturing has been quite popular in the production of computers, televisions, and automobiles.

▶ **Remanufacturing**
The concept of using components of old products in the production of new ones.

PROCESS SELECTION

So far we have discussed issues involved in product design. Though product design is important for a company, it cannot be considered separately from the selection of the process. In this section we will look at issues involved in process design. Then we will show how product design and process selection issues are linked together.

Types of Processes

When you look at different types of companies, ranging from a small coffee shop to IBM, it may seem like there are hundreds of different types of processes. Some locations are small, like your local Starbucks, and some are very large, like a Ford Motor Company plant. Some produce standardized "off-the-shelf" products, like Pepperidge Farm's frozen chocolate cake, and some work with customers to customize their product, like cakes made to order by a gourmet bakery. Though there seem to be large differences between the processes of companies, many have certain processing characteristics in common. In this section we will divide these processes into groups with similar characteristics, allowing us to understand problems inherent with each type of process.

All processes can be grouped into two broad categories: intermittent operations and repetitive operations. These two categories differ in almost every way. Once we understand these differences, we can easily identify organizations based on the category of process they use.

Felicia Martinez/PhotoEdit

Designing a custom-made cake is an example of an intermittent operation.

Walter Hodges/Getty Images, Inc.

An assembly line is an example of a repetitive operation.

▶ **Intermittent operations** Processes used to produce a variety of products with different processing requirements in lower volumes.

Intermittent Operations **Intermittent operations** are used to produce a variety of products with different processing requirements in lower volumes. Examples are an auto body shop, a tool and die shop, or a healthcare facility. Because different products have different processing needs, there is no standard route that all products take through the facility. Instead, resources are grouped by function and the product is routed to each resource as needed. Think about a healthcare facility. Each patient, "the product," is routed to different departments as needed. One patient may need to get an X-ray, go to the lab for blood work, and then go to the examining room. Another patient may need to go to the examining room and then to physical therapy.

To be able to produce products with different processing requirements, intermittent operations tend to be labor intensive rather than capital intensive. Workers need to be able to perform different tasks, depending on the processing needs of the products produced. Often we see skilled and semiskilled workers in this environment, with a fair amount of worker discretion in performing their jobs. Workers need to be flexible and able to perform different tasks as needed for the different products. Equipment in this type of environment is more general-purpose to satisfy different processing requirements. Automation tends to be less common because automation is typically product-specific. Given that many products are being produced with different processing requirements, it is usually not cost efficient to invest in automation for only one product type. Finally, the volume of goods produced is directly tied to the number of customer orders.

▶ **Repetitive operations** Processes used to produce one or a few standardized products in high volume.

Repetitive Operations **Repetitive operations** are used to produce one or a few standardized products in high volume. Examples are a typical assembly line, cafeteria, or automatic car wash. Resources are organized in a line flow to efficiently accommodate production of the product. Note that in this environment it is possible to arrange resources in a line because there is only one type of product. This is directly the opposite of what we find with intermittent operations.

To efficiently produce a large volume of one type of product, these operations tend to be capital intensive rather than labor intensive. An example is "mass-production" operations, which usually have much invested in their facilities and equipment to provide a high degree of product consistency. Often these facilities rely on automation and technology to improve efficiency and increase output rather than on labor skill.

TABLE 3-2

Differences between Intermittent and Repetitive Operations

Decision	Intermittent Operations	Repetitive Operations
Product variety	Great	Small
Degree of standardization	Low	High
Organization of resources	Grouped by function	Line flow to accommodate processing needs
Path of products through facility	In a varied pattern, depending on product needs	Line flow
Factor driving production	Customer orders	Forecast of future demands
Critical resource	Labor-intensive operation (worker skills important)	Capital-intensive operation (equipment automation, technology important)
Type of equipment	General-purpose	Specialized
Degree of automation	Low	High
Throughput time	Longer	Shorter
Work-in-process inventory	More	Less

The volume produced is usually based on a forecast of future demands rather than on direct customer orders.

The most common differences between intermittent and repetitive operations relate to two dimensions: (1) the amount of product volume produced, and (2) the degree of product standardization. Product volume can range from making a unique product one at a time to producing a large number of products at the same time. Product standardization refers to a lack of variety in a particular product. Examples of standardized products are white undershirts, calculators, toasters, and television sets. The type of operation used, including equipment and labor, is quite different if a company produces one product at a time to customer specifications instead of mass production of one standardized product. Specific differences between intermittent and repetitive operations are shown in Table 3-2.

The Continuum of Process Types Dividing processes into two fundamental categories of operations is helpful in our understanding of their general characteristics. To be more detailed, we can further divide each category according to product volume and degree of product standardization, as follows. Intermittent operations can be divided into *project processes* and *batch processes*. Repetitive operations can be divided into *line processes* and *continuous processes*. Figure 3-6 shows a continuum of process types. Next we look at what makes these processes different from each other.

Project process
A type of process used to make a one-at-a-time product exactly to customer specifications.

- **Project processes** are used to make one-of-a-kind products exactly to customer specifications. These processes are used when there is high customization and low product volume, because each product is different. Examples can be seen in construction, shipbuilding, medical procedures, creation of artwork, custom tailoring, and interior design. With project processes the customer is usually involved in deciding on the design of the product. The artistic baker you hired to bake a wedding cake to your specifications uses a project process.

Batch process
A type of process used to produce a small quantity of products in groups or batches based on customer orders or specifications.

- **Batch processes** are used to produce small quantities of products in groups or batches based on customer orders or product specifications. They are also known as job shops. The volumes of each product produced are still small, and there can still be a high degree of customization. Examples can be seen in bakeries, education, and printing shops. The classes you are taking at the university use a batch process.

Line process
A type of process used to produce a large volume of a standardized product.

- **Line processes** are designed to produce a large volume of a standardized product for mass production. They are also known as flow shops, flow lines, or assembly lines. With line processes the product that is produced is made in high volume with little or no customization. Think of a typical assembly line that produces everything from cars, computers, television sets, shoes, candy bars, even food items.

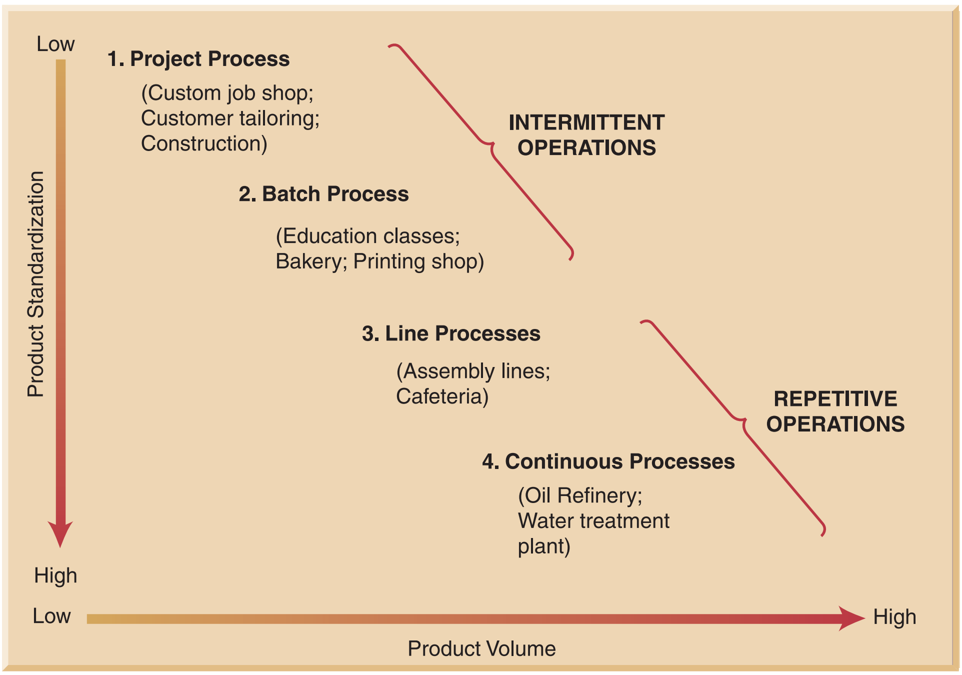
Continuous process
A type of process that operates continually to produce a high volume of a fully standardized product.

- **Continuous processes** operate continually to produce a very high volume of a fully standardized product. Examples include oil refineries, water treatment plants, and certain paint facilities. The products produced by continuous processes are usually in continual rather than discrete units, such as liquid or gas. They usually have a single input and a limited number of outputs. Also, these facilities are usually highly capital intensive and automated.

FIGURE 3-6

Types of processes based on product volume and product standardization

Source: Adapted from Robert H. Hayes and Steven C. Wheelwright, "Link Manufacturing Process and Product Life Cycles," *Harvard Business Review*, January–February, 1979, 133–140.



Note that both project and batch processes have low product volumes and offer customization. The difference is in the volume and degree of customization. Project processes are more extreme cases of intermittent operations compared to batch processes. Also, note that both line and continuous processes primarily produce large volumes of standardized products. Again, the difference is in the volume and degree of standardization. Continuous processes are more extreme cases of high volume and product standardization than are line processes.

Figure 3-6 positions these four process types along the diagonal to show the best process strategies relative to product volume and product customization. Companies whose process strategies do not fall along this diagonal may not have made the best process decisions. Bear in mind, however, that not all companies fit into only one of these categories: a company may use both batch and project processing to good advantage. For example, a bakery that produces breads, cakes, and pastries in batches may also bake and decorate cakes to order.

DESIGNING PROCESSES

Now that we know about different types of processes, let's look at a technique that can help with process design.

Process flow analysis is a technique used for evaluating a process in terms of the sequence of steps from inputs to outputs with the goal of improving its design. One of the most important tools in process flow analysis is a process flowchart. A **process flowchart** is used for viewing the sequence of steps involved in producing the product and the flow of the product through the process. It is useful for seeing the totality of the operation and for identifying potential problem areas.

▶ **Process flow analysis**
A technique used for evaluating a process in terms of the sequence of steps from inputs to outputs with the goal of improving its design.

▶ **Process flowchart**
A chart showing the sequence of steps in producing the product or service.

There is no exact format for designing a flowchart. It can be very simple or highly detailed. The typical symbols used are arrows to represent flows, triangles to represent decision points, inverted triangles to represent storage of goods, and rectangles as tasks. Let's begin by looking at some elements used in developing a flowchart, as shown in Figure 3-7. Shown first, in Figure 3-7(a), are flows between stages in a simple multistage process, which is a process with multiple activities ("stages"). You can see that the arrows indicate a simple flow of materials between the different stages.

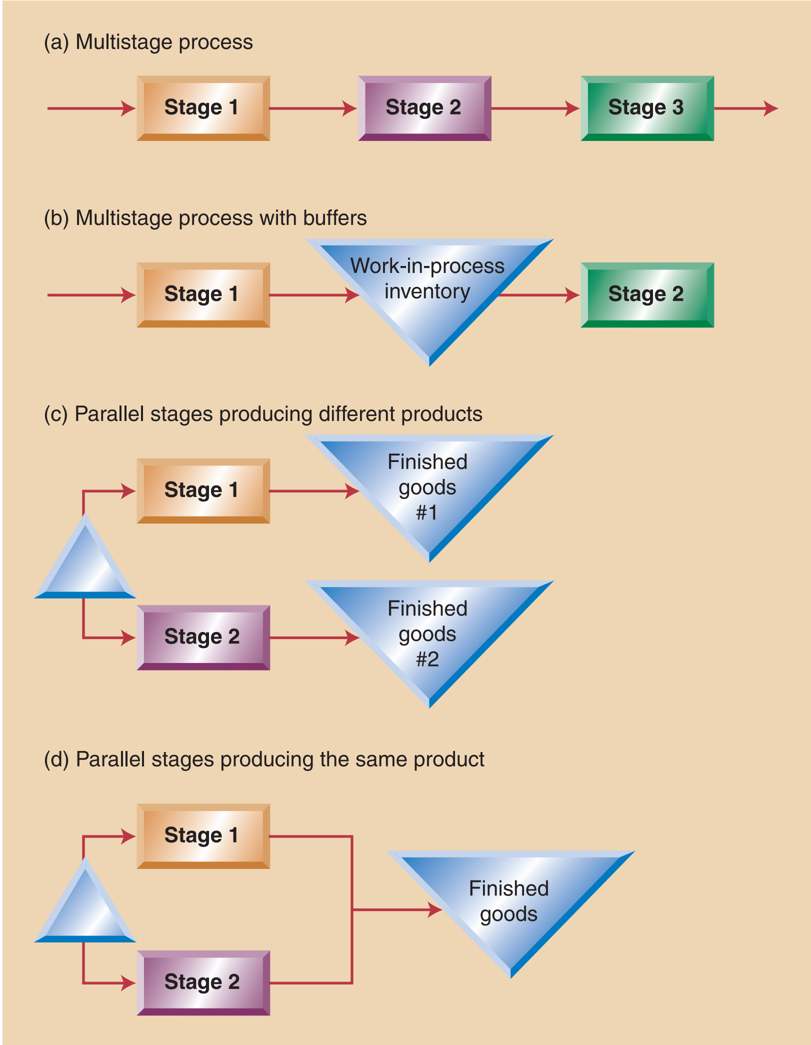
Often, multiple stages have storage areas or "buffers" between them for placement of either partially completed (work-in-process) or fully completed (finished goods) inventory, shown in Figure 3-7(b). This enables the two stages to operate independently of each other. Otherwise, the first stage would have to produce a product at the same exact rate as the second stage. For example, let's say that the first stage of a multistage process produces one product in 40 seconds and the second stage in 60 seconds. That means that for every unit produced the first stage would have to stop and wait 20 seconds for the second stage to finish its work. Because the capacity of the second stage is holding up the speed of the process, it is called a **bottleneck**. Now let's see what happens if the first stage takes 60 seconds to produce a product and the second stage 40 seconds. In this case the first stage becomes the bottleneck, and the second stage has to wait 20 seconds to receive a product. Obviously, the best is for both stages to produce at the same rate, though this is often not possible. Inventory is then placed between the stages to even out differences in production capacity.

▶ **Bottleneck**
Longest task in the process.

Often stages in the production process can be performed in parallel, as shown in Figure 3-7(c) and (d). The two stages can produce different products (c) or the same

FIGURE 3-7

Elements of flowchart development



product (d). Notice that in the latter case this would mean that the capacity of the stage performed in parallel has effectively been doubled.

Now let's look at an illustration of a flowchart using Antonio's Pizzeria as an example. Let's say that Antonio produces three different styles of pizzas to satisfy different types of customers. First are cheese pizzas made with standard ingredients and a standard crust. They are the most popular items, and Antonio makes them ahead of time to ensure that they are always available upon demand. This is called a **make-to-stock strategy**. Second are pizzas that use a standard crust prepared ahead of time but are assembled based on specific customer requests. This is called an **assemble-to-order strategy**. Lastly are pizzas made to order based on specific customer requirements, allowing choices of different types of crusts and toppings. This is called a **make-to-order strategy**. We will look at these product strategies more closely later in this chapter. For now, let's look at the flowcharts for the three processes in Figure 3-8. Notice that although the flowcharts are similar, they show customer interaction at different points in the process.

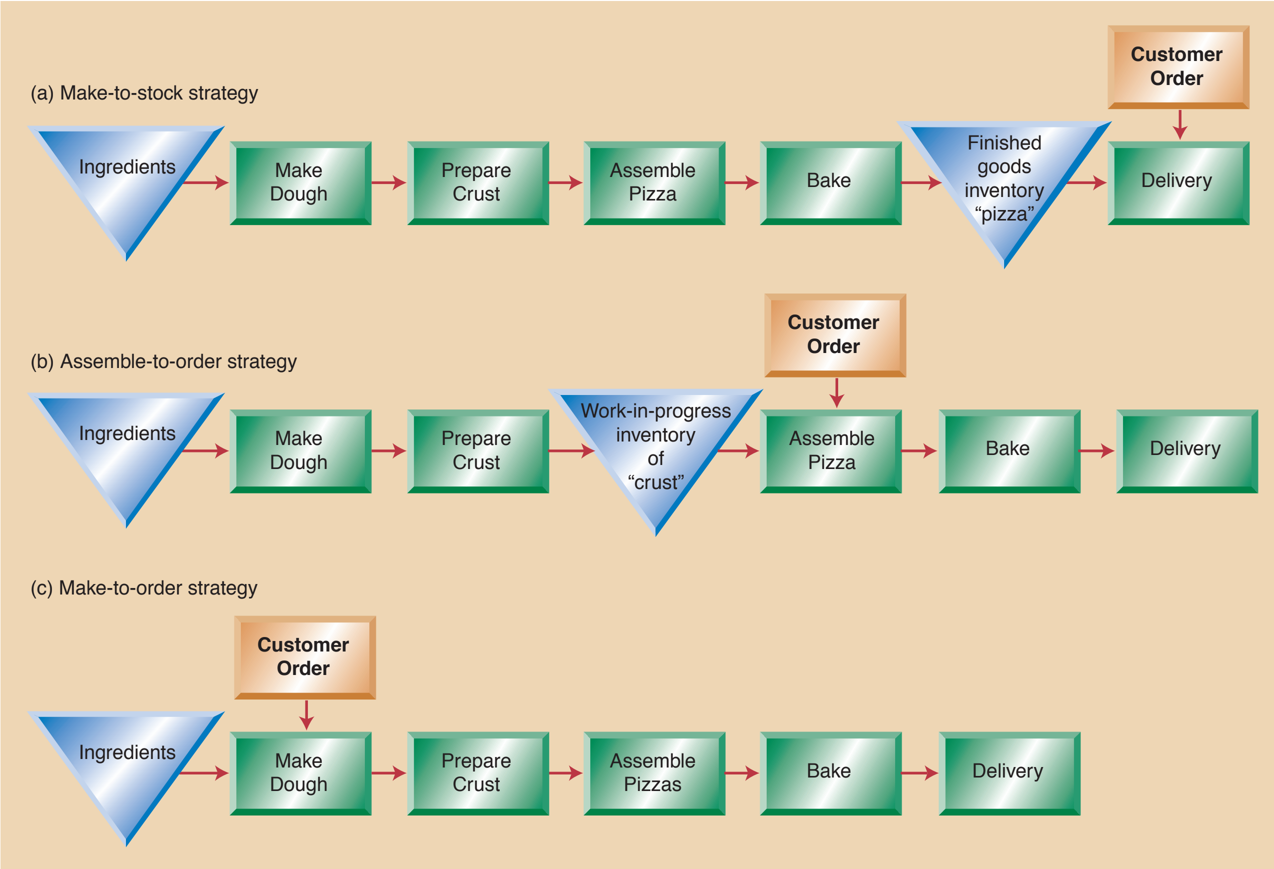
▶ **Make-to-stock strategy**
Produces standard products and services for immediate sale or delivery.

▶ **Assemble-to-order strategy**
Produces standard components that can be combined to customer specifications.

▶ **Make-to-order strategy**
Produces products to customer specifications after an order has been received.

FIGURE 3-8

Flowcharts for different product strategies at Antonio's Pizzeria



Process flowcharts can also be used to map the flow of the customer through the process and to identify potential problem areas. Figure 3-9 shows a flowchart for Antonio's Pizzeria that includes the steps involved in placing and processing a customer order. The points in the process for potential problems are indicated. Management can then monitor these problem areas. The chart could be even more detailed, including information such as frequency of errors or approximate time to complete a task. As you can see, process flowcharts are very useful tools when designing and evaluating processes.

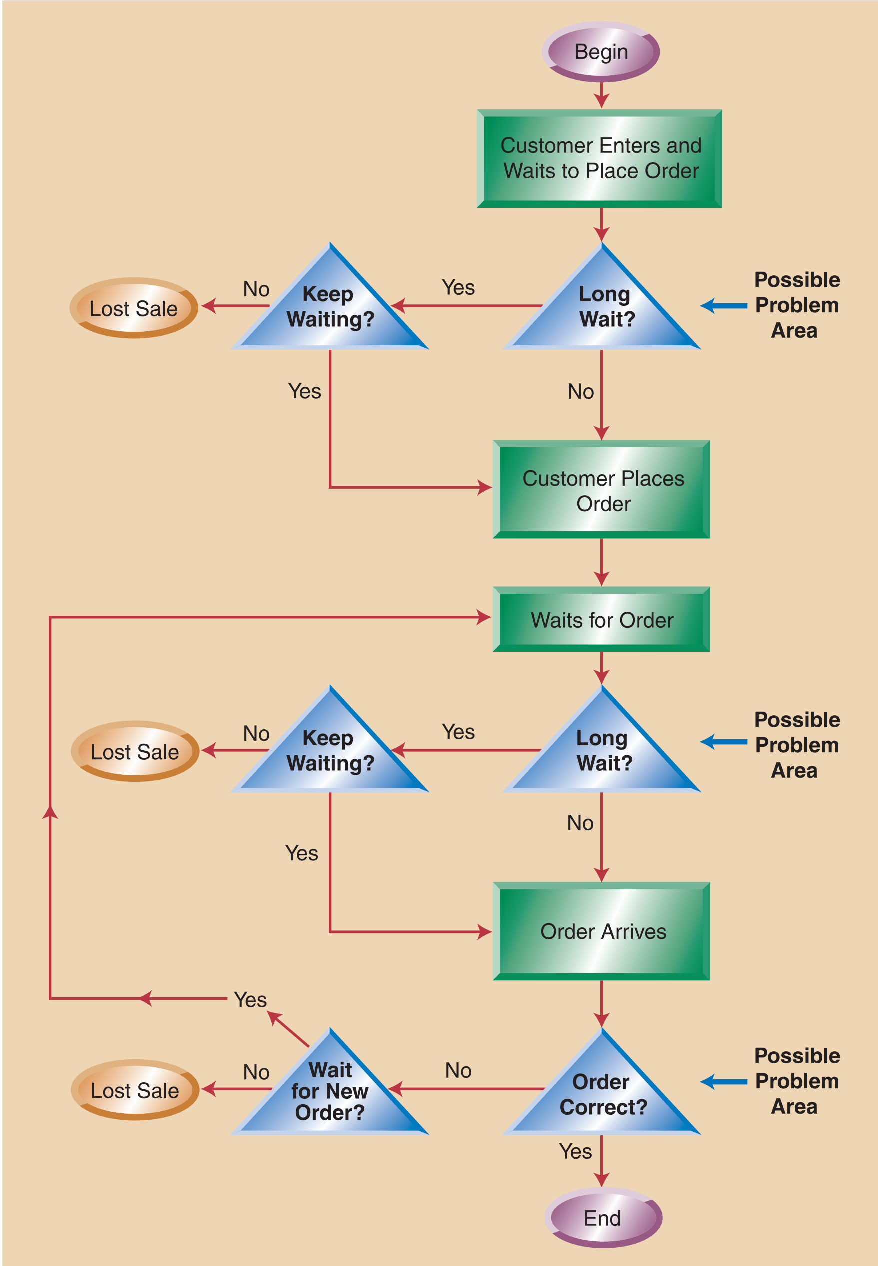
PROCESS PERFORMANCE METRICS

An important way of ensuring that a process is functioning properly is to regularly measure its performance. **Process performance metrics** are measurements of different process characteristics that tell us how a process is performing. Just as accountants and finance managers use financial metrics, operations managers use process performance metrics to determine how a process is performing and how it is changing over time. There are many process performance metrics that focus on different aspects of the process. In this section we will look at some common metrics used by operations managers. These are summarized in Table 3-3 (see page 73).

▶ **Process performance metrics**
Measurements of different process characteristics that tell how a process is performing.

FIGURE 3-9

Process flowchart of customer flow at Antonio's Pizzeria



▶ **Throughput time**
Average amount of time it takes a product to move through the system.

A basic process performance metric is **throughput time**, which is the average amount of time it takes a product to move through the system. This includes the time someone is working on the product as well as the waiting time. A lower throughput time means that more products can move through the system. One goal of process improvement is to reduce throughput time. For example, think about the time spent at your last doctor's appointment. The total amount of time you spent at the facility, regardless of whether you were waiting, talking with the physician, or having lab work performed, is throughput time.

Quite possibly much of the time at your last doctor's appointment was spent waiting. An important metric that measures how much wasted time exists in a process is

TABLE 3-3

Process Performance Metrics

Measure	Definition
1. Throughput time	Average amount of time product takes to move through the system
2. Process velocity $= \dfrac{\text{throughput time}}{\text{value-added time}}$	A measure of wasted time in the system
3. Productivity $= \dfrac{\text{output}}{\text{input}}$	A measure of how well a company uses its resources
4. Utilization $= \dfrac{\text{time a resource used}}{\text{time a resource available}}$	The proportion of time a resource is actually used
5. Efficiency $= \dfrac{\text{actual output}}{\text{standard output}}$	Measures performance relative to a standard

process velocity. Process velocity is computed as a ratio of throughput time to value-added time:

$$\text{Process velocity} = \frac{\text{throughput time}}{\text{value-added time}}$$

where value-added time is the time spent actually working on the product. Notice that the closer this ratio is to 1.00, the lower the amount of time the product spends on non-value-adding activities (e.g., waiting). Again recall your last doctor's appointment. What was the value-added time? What was the throughput time? Can you estimate the process velocity?

Another important metric is **productivity**, which is the ratio of outputs over inputs. Productivity measures how well a company converts its inputs to outputs. Productivity was discussed in detail in Chapter 2, so we will not repeat its computation here. Also important is **utilization**, which is the ratio of the time a resource is actually used versus the time it is available for use. Unlike productivity, which tends to focus on financial measures (e.g., dollars of output), utilization measures the actual time that a resource (e.g., equipment or labor) is being used. Last, **efficiency** is a metric that measures actual output relative to some standard of output. It tells us whether we are performing at, above, or below standard.

▶ **Process velocity**
Ratio of throughput time to value-added time.

▶ **Productivity**
Ratio of outputs over inputs.

▶ **Utilization**
Ratio of time a resource is used to time it is available for use.

▶ **Efficiency**
Ratio of actual output to standard output.

EXAMPLE 3.2

Measuring Process Performance

Frantz Title Company is analyzing its operation in an effort to improve performance. The following data have been collected:

It takes an average of 4 hours to process and close a title, with value-added time estimated at 30 minutes per title.

Each title officer is on payroll for 8 hours per day, though working 6 hours per day on average, accounting for lunches and breaks. Industry standard for labor utilization is 80 percent.

The company closes on 8 titles per day, with an industry standard of 10 titles per day for a comparable facility.

Determine process velocity, labor utilization, and efficiency for the company. Can you draw any conclusions?

- **Before You Begin:** When computing process performance metrics, be careful to make sure you use consistent units in the numerator and denominator of the equation you are using.

- **Solution:**

$$\text{Process velocity} = \frac{\text{throughput time}}{\text{value-added time}} = \frac{4 \text{ hours/title}}{\frac{1}{2} \text{ hour/title}} = 8$$

$$\text{Labor utilization} = \frac{6 \text{ hours/day}}{8 \text{ hours/day}} = 0.75 \text{ or } 75\%$$

$$\text{Efficiency} = \frac{8 \text{ titles/day}}{10 \text{ titles/day}} = 0.80 \text{ or } 80\%$$

A process velocity of 8 indicates that the amount of time spent on non-value-added activities is 8 times that of value-added activities. Also, labor utilization and efficiency are both below standard.

Before You Go On

Make sure that you understand the key issues in product design. Be familiar with the different stages of the product life cycle. Recall that products in the early stages of the life cycle are still being refined based on the needs of the market. This includes product characteristics and features. At this stage the market for the product has not yet been fully developed, and product volumes have not reached their peak. By contrast, products in the later stages of their life cycle have well-developed characteristics, and demand volumes for them are fairly stable.

Review the different types of processes and their characteristics. Recall that intermittent processes are designed to produce products with different processing requirements in smaller volumes. Repetitive operations, on the other hand, are designed for one or a few types of products produced in high volumes.

Next we discuss how product design and process selection decisions are interrelated.

LINKING PRODUCT DESIGN AND PROCESS SELECTION

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Decisions concerning product design and process selection are directly linked and cannot be made independently of one another. The type of product a company produces defines the type of operation needed. The type of operation needed, in turn, defines many other aspects of the organization. This includes how a company competes in the marketplace (competitive priorities), the type or equipment and its arrangement in the facility, the type of organizational structure, and future types of products that can be produced by the facility. Table 3-4 summarizes some key decisions and

TABLE 3-4

Differences in Key Organizational Decisions for Different Types of Operations

Decision	Intermittent Operations	Repetitive Operations
Product design	Early stage of product life cycle	Later stage of product life cycle
Competitive priorities	Delivery, flexibility, and quality	Cost and quality
Facility layout	Resources grouped by function	Resources arranged in a line
Product strategy	Make-to-order/assemble-to-order	Make-to-stock
Vertical integration	Low	High

how they differ for intermittent and repetitive types of operations. Next we look at each of these decision areas.

Product Design Decisions

Intermittent and repetitive operations typically focus on producing products in different stages of the product life cycle. Intermittent operations focus on products in the early stage of the life cycle because facilities are general-purpose and can be adapted to the needs of the product. Because products in the early stage of the life cycle are still being refined, intermittent operations are ideally suited to them. Also, demand volumes for these products are still uncertain, and intermittent operations are designed to focus on producing lower volumes of products with differing characteristics.

Once a product reaches the later stages of the life cycle, both its product features and its demand volume are predictable. As volumes are typically larger at this stage, a facility that is dedicated to producing a large volume of one type of product is best from both efficiency and cost perspectives. This is what a repetitive operation provides. Recall that repetitive operations are capital intensive, with much automation dedicated to the efficient production of one type of product. It would not be a good decision to invest such a large amount of resources for a product that is uncertain relative to its features or market. However, once a product is well defined with a sizable market, repetitive types of operations are a better business alternative. This is why repetitive operations tend to focus on products in the later stages of their life cycle.

The product focus of both types of operations has significant implications for a company's future product choices. Once a company has an intermittent operation in place, designed to produce a variety of products in low volumes, it is a poor strategic decision to pursue production of a highly standardized product in the same facility. The same holds true for attempting to produce a newly introduced product in a repetitive operation.

The differences between the two types of operations are great, including the way they are managed. Not understanding their differences is a mistake often made by companies. A company may be very successful at managing a repetitive operation that produces a standardized product. Management may then see an opportunity involving products in the early stage of the life cycle. Not understanding the differences in the operational requirements, management may decide to produce this new product by applying their "know-how." The results can prove disastrous.

LINKS TO PRACTICE

The Babcock & Wilcox Company
www.babcock.com

Michael Rosenfeld/Stone/Getty Images, Inc.

The problems that can arise when a company does not understand the differences between intermittent and repetitive operations are illustrated by the experience of The Babcock & Wilcox Company in the late 1960s. B & W was very successful at producing fossil-fuel boilers, a standardized product made via repetitive operation. Then the company decided to pursue production of nuclear pressure vessels, a new product in the early stages of its life cycle that required an intermittent operation. B & W saw the nuclear pressure vessels as a wave of the future. Because they were successful at producing boilers, they believed they could apply those same skills to production of the new product. They began managing the production of nuclear

pressure vessels—an intermittent operation—as if it were a repetitive operation. They focused primarily on cost rather than delivery, did not give enough time for product refinement, and did not invest in labor skills necessary for a new product. Consequently, the venture failed, and the company almost went out of business. It was saved by its success in the production of boilers, to which it was able to return.

Competitive Priorities

The decision of how a company will compete in the marketplace—its competitive priorities—is largely affected by the type of operation it has in place. Intermittent operations are typically less competitive on cost than repetitive operations. The reason is that repetitive operations mass-produce a large volume of one product. The cost of the product is spread over a large volume, allowing the company to offer that product at a comparatively lower price.

Think about the cost difference you would incur if you decided to buy a business suit "off the rack" from your local department store (produced by a repetitive operation) versus having it custom made by a tailor (an intermittent operation). Certainly a custom-made suit would cost considerably more. The same product produced by a repetitive operation typically costs less than one made by an intermittent operation. However, intermittent operations have their own advantages. Having a custom-made suit allows you to choose precisely what you want in style, color, texture, and fit. Also, if you were not satisfied, you could easily return it for adjustments and alterations. Intermittent operations compete more on flexibility and delivery compared to continuous operations.

Today all organizations understand the importance of quality. However, the elements of quality that a company focuses on may be different depending on the type of operation used. Repetitive operations provide greater consistency among products. The first and last products made in the day are almost identical. Intermittent operations, on the other hand, offer greater variety of features and workmanship not available with mass production.

It is important that companies understand the competitive priorities best suited for the type of process that they use. It would not be a good strategic decision for an intermittent operation to try to compete primarily on cost, as it would not be very successful. Similarly, the primary competitive priority for a repetitive operation should not be variety of features because this would take away from the efficiency of the process design.

Facility Layout

Facility layout, covered in Chapter 10, is concerned with the arrangement of resources in a facility to enhance the production process. If resources are not arranged properly, a company will have inefficiency and waste. The type of process a company uses directly affects the facility layout and the inherent problems encountered.

Intermittent operations resources are grouped based on similar processes or functions. There is no one typical product that is produced; rather, a large variety of items are produced in low volumes, each with its own unique processing needs. Since no one product justifies the dedication of an entire facility, resources are grouped based on their function. Products are then moved from resource to resource, based on their processing needs. The challenge with intermittent operations is to arrange the location of resources to maximize efficiency and minimize waste of movement. If the intermittent

operation has not been designed properly, many products will be moved long distances. This type of movement adds nothing to the value of the product and contributes to waste. Any two work centers that have much movement between them should be placed close to one another. However, this often means that another work center will have to be moved out of the way. This can make the problem fairly challenging.

Intermittent operations are less efficient and have longer production times due to the nature of the layout. Material handling costs tend to be high and resource scheduling is a challenge. Intermittent operations are common in practice. Examples include a doctor's office or a hospital. Departments are grouped based on their function, with examining rooms in one area, lab in another, and X-rays in a third. Patients are moved from one department to another based on their needs. Another example is a bakery that makes custom cakes and pastries. The work centers are set up to perform different functions, such as making different types of dough, different types of fillings, and different types of icing and decorations. The product is routed to different workstations depending on the product requirements. Some cakes have the filling in the center (e.g., Boston cream pie), others only on top (e.g., sheet cake), and some have no filling at all (e.g., pound cake).

Repetitive operations have resources arranged in sequence to allow for efficient production of a standardized product. Since only one product or a few highly similar products are being produced, all resources are arranged to efficiently meet production needs. Examples are seen on an assembly line, in a cafeteria, or even a car wash. Numerous products, from breakfast cereals to computers, are made using repetitive operations.

Though repetitive operations have faster processing rates, lower material handling costs, and greater efficiency than intermittent operations, they also have their shortcomings. Resources are highly specialized and the operation is inflexible relative to the market. This type of operation cannot respond rapidly to changes in market needs for the products or to changes in demand volume. The challenge is to arrange workstations in sequence and designate the jobs that will be performed by each to produce the product in the most efficient way possible. Figure 3-10 illustrates the differences in facility layout between intermittent and repetitive operations.

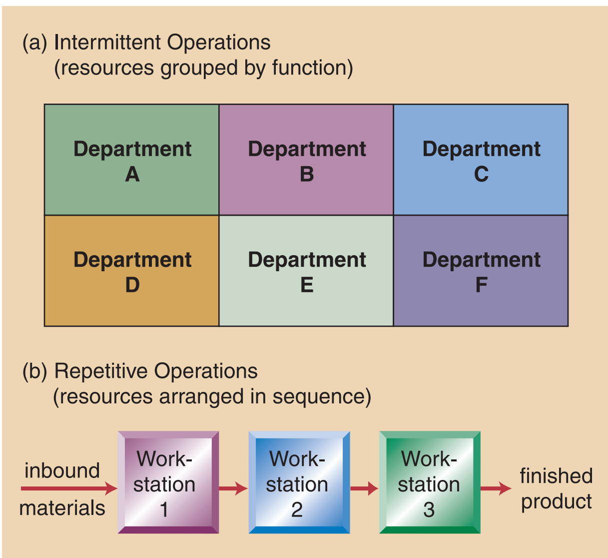
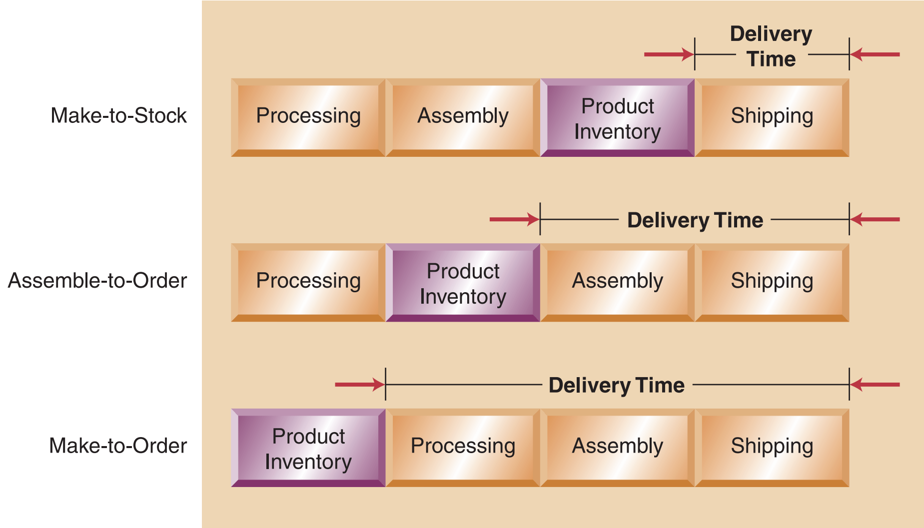


FIGURE 3-10

Facility layouts for intermittent versus repetitive operations

FIGURE 3-11

Product and service strategy options



Product and Service Strategy

The type of operation a company has in place is directly related to its product and service strategy. As we learned earlier in this chapter in the example of Antonio's Pizzeria, product and service strategies can be classified as make-to-stock, assemble-to-order, and make-to-order. These strategies differ by the length of their delivery lead time, which is the amount of time from when the order is received to when the product is delivered. These strategies also differ by the degree of product customization. Figure 3-11 illustrates these differences.

Make-to-stock is a strategy that produces finished products for immediate sale or delivery, in anticipation of demand. Companies using this strategy produce a standardized product in larger volumes. Typically, this strategy is seen in repetitive operations. Delivery lead time is the shortest, but the customer has no involvement in product design. Examples include off-the-shelf retail apparel, soft drinks, standard automotive parts, or airline flights. A hamburger patty at a fast-food restaurant such as McDonald's or Burger King is made-to-stock, as is a taco at Taco Bell. As a customer you gain speed of delivery but lose the ability to customize the product.

Assemble-to-order strategy, also known as build-to-order, produces standard components that can be combined to customer specifications. Delivery time is longer than in the make-to-stock strategy but allows for some customization. Examples include computer systems, prefabricated furniture with choices of fabric colors, or vacation packages with standard options.

Make-to-order is a strategy used to produce products to customer specifications after an order has been received. The delivery time is longest, and product volumes are low. Examples are custom-made clothing, custom-built homes, and customized professional services. Ordering a hamburger to your liking in a sit-down restaurant is another example of this strategy. This strategy is best for an intermittent operation.

Degree of Vertical Integration

The larger the number of processes performed by a company in the chain from raw materials to product delivery, the higher the vertical integration. Vertical integration is a strategic decision that should support the future growth direction of the company.

Vertical integration is a good strategic option when there are high volumes of a small variety of input materials, as is the case with repetitive operations. The reason is that the high volume and narrow variety of input material allow task specialization and cost justification. An example is Dole Food Company, which owns and controls most of its canned pineapple production from pineapple farms to the processing plant. The company has chosen to be vertically integrated so as to have greater control of costs and product quality.

It is typically not a good strategic decision to vertically integrate into specialized processes that provide inputs in small volumes. This would be the case for intermittent operations. For example, let's consider a bakery that makes a variety of different types of cakes and pies. Maybe the bakery purchases different fillings from different sources, such as apple pie filling from one company, chocolate filling from another, and cream filling from a third. If the company were to purchase production of the apple filling, it would not gain much strategically because it still relies on other suppliers. In this case, outsourcing may be a better choice. However, if the bakery shifted its production to making only apple pies, then the vertical integration might be a good choice.

In summary, vertical integration is typically a better strategic decision for repetitive operations. For intermittent operations it is generally a poor strategic choice.

TECHNOLOGY DECISIONS

Advancements in technology have had the greatest impact on process design decisions. Technological advances have enabled companies to produce products faster, with better quality, at a lower cost. Many processes that were not imaginable only a few years ago have been made possible through technology. In this section we look at some of the greatest impacts technology has had on process design.

Information Technology

Information technology (**IT**) is technology that enables storage, processing, and communication of information within and between firms. It is also used to organize information to help managers with decision making. One type of information technology we are all familiar with is the *Internet*, which has had the greatest impact on the way companies conduct business. The Internet has linked trading partners—customers, buyers, and suppliers—and has created electronic commerce and the virtual marketplace.

► **Information technology (IT)**
Technology that enables storage, processing, and communication of information within and between firms.

Enterprise software is another powerful information technology, such as **enterprise resource planning** (**ERP**). These are large software programs used for planning and coordinating all resources throughout the entire enterprise. They allow data sharing and communication within and outside of the firm, enabling collaborative decision making. We will learn more about ERP in Chapter 14.

► **Enterprise resource planning (ERP)**
Large software programs used for planning and coordinating all resources throughout the entire enterprise.

Other examples of IT include *wireless communication technologies*. We are all familiar with cellular phones and pagers in our own lives. These technologies can also significantly improve business operations. For example, wireless homing devices and wearable computers are being used in warehouses to quickly guide workers to locations of goods. Wireless technologies enhanced by satellite transmission can rapidly transmit information from one source to another. For example, Wal-Mart uses company-owned satellites to automatically transmit point-of-sale data to computers at replenishment warehouses.

▶ **Global positioning systems (GPS)**
A type of wireless technology that uses satellite transmission to communicate exact locations.

Global positioning systems (**GPS**) comprise another type of wireless technology that uses satellite transmission to communicate exact locations. GPS was originally developed by the Department of Defense in 1978 in order to help coordinate U.S. military operations. Today GPS has numerous business and individual applications. Large trucking companies use GPS technology to identify the exact locations of their vehicles. Farmers use GPS while riding on tractors to identify their exact location and apply the proper mix of nutrients to the correct plot of land. GPS capability is also available for personal use in handheld computers, such as the Palm Garmin iQue, that can identify the person's location and plot a route to a destination.

LINKS TO PRACTICE

Using GPS Technology in Product Advertising

Alamy Images

GPS has even found its use in advertising. For example, Nielsen Media Research, the firm known for rating television shows, is using GPS to test billboard advertising. The company has recruited a sample of adults with known demographic characteristics and is using GPS to monitor their minute-by-minute movements. This information will then be used to determine the best placement for particular billboard advertisements targeted to the particular demographic group.

▶ **Radio frequency identification (RFID)**
A wireless technology that uses memory chips equipped with radio antennas attached to objects used to transmit streams of data.

Radio frequency identification (**RFID**) is another wireless technology that promises to dramatically change business operations. RFID uses memory chips equipped with tiny radio antennas that can be attached to objects to transmit streams of data about the object. For example, RFID can be used to identify any product movement, reveal a missing product's location, or have a shipment of products "announce" their arrival. Empty store shelves can signal that it is time for replenishment using RFID, or low inventories can signal the vendor that it is time to ship more products. RFID can also be used in the service environment, enabling innovative applications in locating and tracking people and assets. In fact, RFID has the potential to become the backbone of an infrastructure that can identify and track billions of individual objects all over the world, in real time.

A big adopter of RFID is Wal-Mart, which is investing heavily in RFID tags for its warehouses. Wal-Mart went live with RFID in January 2005 after pilot testing them at distribution centers in Dallas. The company has already seen a return on its investment. For example, out-of-stock items that are RFID tagged are replenished three times faster than before. The company is also experimenting with adding sensor tags to perishable items. This way, for example, it can track how long a crate of bananas has been in transit and how fresh it is.

Automation

▶ **Automation**
Using machinery to perform work without human operators.

An important decision in designing processes is whether the firm should automate, to what degree, and the type of automation that should be used. **Automation** is the use of machinery able to perform work without human operators and can involve a single machine or an entire factory. Although there are tremendous advantages to automation,

there are also disadvantages. Companies need to consider these carefully before making the final decision.

Automation has the advantage of product consistency and ability to efficiently produce large volumes of product. With automated equipment, the last part made in the day will be exactly like the first one made. Because automation brings consistency, quality tends to be higher and easier to monitor. Production can flow uninterrupted throughout the day, without breaks for lunch, and there is no fatigue factor.

However, automation does have its disadvantages. First, automation is typically very costly. These costs can be justified only by a high volume of production. Second, automation is typically not flexible in accommodating product and process changes. Therefore, automation would probably not be good for products in the early stages of their life cycle or for products with short life cycles. Automation needs to be viewed as another capital investment decision: financial payback is critical. For all these reasons automation is typically less present in intermittent than in repetitive operations.

Automated Material Handling In the past, the primary method of moving products was the conveyor in the form of belts or chains. Today's material handling devices can read bar codes that tell them which location to go to and which are capable of moving in many directions. One such device is an *automated guided vehicle* (*AGV*), a small battery-driven truck that moves materials from one location to the other. The AGV is not operated by a human and takes its directions from either an onboard or central computer. Even AGVs have become more sophisticated over time. The older models followed a cable that was installed under the floor. The newer models follow optical paths and can go anywhere there is aisle space, even avoiding piles of inventory in their way. One of the biggest advantages of AGVs is that they can pretty much go anywhere, as compared to traditional conveyor belts. Managers can use them to move materials wherever they are needed.

Jeff Greenberg/The Image Works

Handheld scanner reading a bar code.

Another type of automated material handling includes *automated storage and retrieval systems* (*AS/RSs*), which are basically automated warehouses. AS/RSs use AGVs to move material and also computer-controlled racks and storage bins. The storage bins can typically rotate like a carousel, so that the desired storage bin is available for either storage or retrieval. All this is controlled by a computer that keeps track of the exact location and quantity of each item and controls how much will be stored or retrieved in a particular area. AS/RSs can have great advantages over traditional warehouses. Though they are much more costly to operate, they are also much more efficient and accurate.

Flexible Manufacturing Systems (FMS) A **flexible manufacturing system** (**FMS**) is a type of automation system that combines the flexibility of intermittent operations with the efficiency of repetitive operations. As you can see by the definition, this is a *system* of automated machines, not just a single machine. An FMS consists of groups of computer-controlled machines and/or robots, automated handling devices for moving, loading, and unloading, and a computer-control center.

▶ **Flexible manufacturing system (FMS)**
A type of automated system that combines the flexibility of intermittent operations with the efficiency of continuous operations.

Based on the instructions from the computer-control center, parts and materials are automatically moved to appropriate machines or robots. The machines perform their tasks and then the parts are moved to the next set of machines, where the parts automatically are loaded and unloaded. The routes taken by each product are determined with the goal of maximizing the efficiency of the operation. Also, the FMS "knows" when one machine is down due to maintenance or if there is a backlog of work on a machine, and it will automatically route the materials to an available machine.

Michael Rosenfeld/Stone/
Getty Images

Production line robot placing windshield on car

Flexible manufacturing systems are still fairly limited in the variety of products that they handle. Usually they can only produce similar products from the same family. For this reason, and because of their high cost, flexible manufacturing systems are not very widespread. A decision to use an FMS needs to be long-term and strategic, requiring a sizable financial outlay.

Robotics A robot in manufacturing is usually nothing more than a mechanical arm with a power supply and a computer-control mechanism that controls the movements of the arm. The arm can be used for many tasks, such as painting, welding, assembly, and loading and unloading of machines. Robots are excellent for physically dangerous jobs such as working with radioactive or toxic materials. Also, robots can work 24 hours a day to produce a highly consistent product.

Robots vary in their degree of sophistication. Some robots are fairly simple and follow a repetitive set of instructions. Other robots follow complex instructions, and some can be programmed to recognize objects and even make simple decisions. One type of automation similar to simple robotics is the **numerically controlled (NC) machine**. NC machines are controlled by a computer and can do a variety of tasks such as drilling, boring, or turning parts of different sizes and shapes. Factories of the future will most likely be composed of a number of robots and NC machines working together.

► **Numerically controlled (NC) machine**
A machine controlled by a computer that can perform a variety of tasks.

The use of robots has not been very widespread in U.S. firms. However, this is an area that can provide a competitive advantage for a company. Cost justification should consider not only reduction in labor costs but also the increased flexibility of operation and improvement in quality. The cost of robots can vary greatly and depends on the robots' size and capabilities. Generally, it is best for a company to consider purchasing multiple robots or forms of automation to spread the costs of maintenance and software support. Also, the decision to purchase automation such as robotics needs to be a long-term strategic one that considers the totality of the production process. Otherwise, the company may have one robot working 24 hours a day and piling up inventory while it waits for the other processes to catch up.

LINKS TO PRACTICE

Performing Robotic Surgery

©AP/Wide World Photos

Robots can be used to improve operations of almost any business—even literal "operations." Increasingly, robots have been used to perform certain medical surgeries. For example, at New York University doctors use minimally invasive robotic surgery to repair human heart valves. To perform the surgery, doctors use a robot arm to cut a 6-cm incision between the ribs and to place an endoscope that allows the surgeons to see what they are doing. The robot arm is controlled through a complex robotic surgical system. The doctors, seated at a workstation, manipulate conventional surgical instruments while the robotic surgical system mirrors these movements on an ultra-fine scale. The advantage of robots is that they can perform delicately fine, small, motor movements, have consistent finger dexterity, and require only tiny incisions. The prediction is that robots will become involved in performing many surgeries, such as eye surgery, neurosurgery, and cosmetic surgery.

e-Manufacturing

Today's Web-based environment has created numerous opportunities for business collaboration. This includes collaboration in product and process design, where customers, buyers, and designers can share information and jointly make decisions in real time. Let's look at some of the computer systems that can aid e-manufacturing.

Computer-Aided Design (CAD) **Computer-aided design** (**CAD**) is a system that uses computer graphics to design new products. Gone are the days of drafting designs by hand. Today's powerful desktop computers combined with graphics software allow the designer to create drawings on the computer screen and then manipulate them geometrically to be viewed from any angle. With CAD the designer can rotate the object, split it to view the inside, and magnify certain sections for closer view.

▶ **Computer-aided design (CAD)**
A system that uses computer graphics to design new products.

CAD can also perform other functions. Engineering design calculations can be performed to test the reactions of the design to stress and to evaluate strength of materials. This is called *computer-aided engineering* (*CAE*). For example, the designer can test how different dimensions, tolerances, and materials respond to different conditions such as rough handling or high temperatures. The designer can use the computer to compare alternative designs and determine the best design for a given set of conditions. The designer can also perform cost analysis on the design, evaluating the advantages of different types of materials.

Another advantage of CAD is that it can be linked to manufacturing. We have already discussed the importance of linking product design to process selection. Through CAD this integration is made easy. *Computer-aided manufacturing* (*CAM*) is the process of controlling manufacturing through computers. Since the product designs are stored in the computer database, the equipment and tools needed can easily be simulated to match up with the processing needs. Efficiencies of various machine choices and different process alternatives can be computed.

Geoff Tompkinson/Science Photo Library/Photo Researchers Inc.

Using computer technology in molecular modeling of proteins

CAD can dramatically increase the speed and flexibility of the design process. Designs can be made on the computer screen and printed out when desired. Electronic versions can be shared by many members of the organization for their input. Also, electronic versions can be archived and compared to future versions. The designer can catalog features based on their characteristics—a very valuable feature. As future product designs are being considered, the designer can quickly retrieve certain features from past designs and test them for inclusion in the design being currently developed. Also, by using *collaborative product commerce* (*CPC*) *software*, sharing designs with suppliers is possible.

Computer-Integrated Manufacturing **Computer-integrated manufacturing** (**CIM**) is a term used to describe the integration of product design, process planning, and manufacturing using an integrated computer system. Computer-integrated manufacturing systems vary greatly in their complexity. Simple systems might integrate computer-aided design (CAD) with some numerically controlled machines (NC machines). A complex system, on the other hand, might integrate purchasing, scheduling, inventory control, and distribution, in addition to the other areas of product design.

▶ **Computer-integrated manufacturing (CIM)**
A term used to describe the integration of product design, process planning, and manufacturing using an integrated computer system.

The key element of CIM is the integration of different parts of the operation process to achieve greater responsiveness and flexibility. The purpose of CIM is to improve how quickly the company can respond to customer needs in terms of product design and availability, as well as quality and productivity, and to improve overall efficiency.

DESIGNING SERVICES

Most of the issues discussed in this chapter are as applicable to service organizations as they are to manufacturing. However, there are issues unique to services that pose special challenges for service design.

Most of us think we know what is needed to run a good service organization. After all, we encounter services almost every day, at banks, fast-food restaurants, doctor's offices, barber shops, grocery stores, and even the university. We have all experienced poor service quality and would gladly offer advice as to how we think it could be better. However, there are some very important features of services you may not have thought about. Let's see what they are.

How Are Services Different from Manufacturing?

In Chapter 1 we learned about two basic features that make service organizations different from manufacturing. These are the intangibility of the product produced and the high degree of customer contact. Next we briefly review these and see how they impact service design.

Intangible Product Service organizations produce an intangible product, which cannot be touched or seen. It cannot be stored in inventory for later use or traded in for another model. The service produced is *experienced* by the customer. The design of the service needs to specify exactly what the customer is supposed to experience. For example, it may be relaxation, comfort, and pampering, such as offered by Canyon Ranch Spa. It may be efficiency and speed, such as offered by FedEx. Defining the customer experience is part of the service design. It requires identifying precisely what the customer is going to feel and think and consequently how he or she is going to behave. This is not always as easy as it might seem.

MKT

The experience of the customer is directly related to customer expectations. For services to be successful, the customer experience needs to meet or even exceed these expectations. However, customer expectations can greatly vary depending on the type of customer and customer demographic, including customer age, gender, background, and knowledge. The expectation is developed through product marketing to a particular market segment. It is highly important in designing the service to identify the target market the service is geared to and to create the correct expectation.

High Degree of Customer Contact Service organizations typically have a high degree of customer contact. The customer is often present while the service is being delivered, such as at a theater, restaurant, or bank. Also, the contact between the customer and service provider is often the service itself, such as what you experience at a doctor's office. For a service to be successful, this contact needs to be a positive experience for the customer, and this depends greatly on the service provider.

Unfortunately, since services often have multiple service providers, there can be great variation in the type of service delivered. We have all had experiences where the service of one organization varied greatly depending on the skills of the service provider. This could be a hairdresser at a hair salon, a food server at a restaurant, or a teller at a bank. We have all heard people say something similar to "I often have dinner at Aussie Steak Grill and I insist that Jenny be my server." Similarly, someone might say, "I go to Olentangy Family Physicians, but I won't see Dr. Jekyl because he is rude and unfriendly." For a service to be successful, the service experience must be consistent at

all times. This requires close quality management to ensure high consistency and reliability. Many of the procedures used in manufacturing to ensure high quality, such as standardization and simplification, are used in services as well. Fast-food restaurants such as McDonald's and Wendy's are known for their consistency. The same is true of hotel chains such as Holiday Inn and Embassy Suites.

To ensure that the service contact is a positive experience for the customer, employees of the service need to have training that encompasses a great array of skills that include courtesy, friendliness, and overall disposition. The service company also needs to structure the proper incentive system to motivate employees.

How Are Services Classified?

We can classify service organizations based on similar characteristics in order to understand them better. A common way to classify services is based on the degree of customer contact. This is illustrated in Figure 3-12.

Services with low customer contact are called "quasi-manufacturing." These firms have a high degree of service standardization, have higher sales volumes, and are typically less labor intensive. These firms have almost no face-to-face contact with customers and are in many ways similar to manufacturing operations. Examples include warehouses, distribution centers, environmental testing laboratories, and back-office operations.

Services with high customer contact are called "pure services." These firms have high face-to-face contact and are highly labor intensive. There is low product standardization, as each customer has unique requirements, and sales volumes tend to be low. Pure

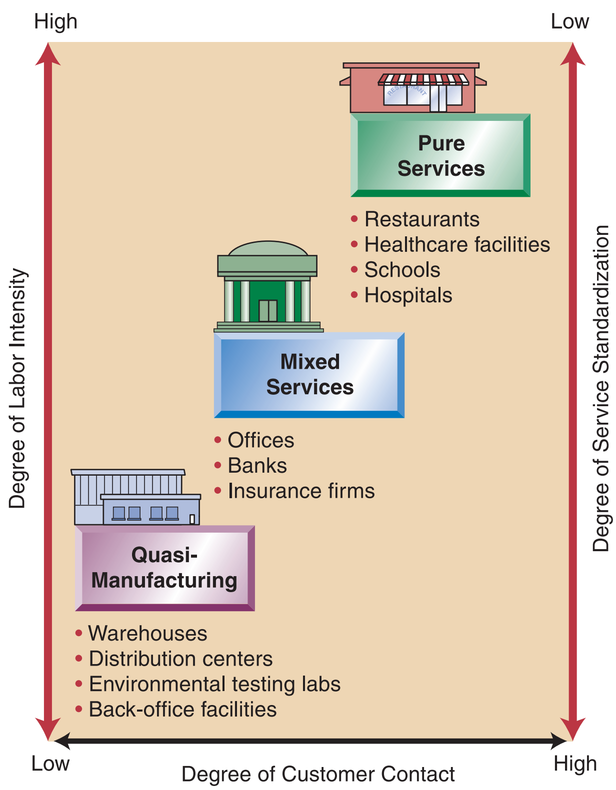


FIGURE 3-12

Classification of service operations

service firms have an environment of lowest system efficiency compared to other service firms. The reason is that the service is typically customized. As each customer has unique requirements, there is less predictability in managing the operating environment. Examples include hospitals, restaurants, barber shops, and beauty salons.

Services that combine elements of both of these extremes are called "mixed services." Some parts of their operation have face-to-face customer contact, though others do not. They include offices, banks, and insurance firms.

It is important to understand that companies with different levels of customer contact need to be managed differently. These differences also apply to high-contact and low-contact areas of firms. For example, companies should specifically hire people-oriented workers for high-contact areas, whereas technical skills are more important in low-contact areas. Also, noncontact activities should be partitioned from the customer to avoid disruptions in the flow of work. Noncontact areas can be managed borrowing tools from manufacturing, whereas high-contact areas need to focus on accommodating the customer.

The Service Package

The really successful service organizations do not happen spontaneously. They are carefully thought out and planned, down to every employee action. To design a successful service, we must first start with a service concept or idea, which needs to be very comprehensive. We have learned that when purchasing a service, customers actually buy a **service package** or service bundle. The service package is a grouping of features that are purchased together as part of the service. There are three elements of the service package: (1) the physical goods, (2) the sensual benefits, and (3) the psychological benefits. The physical goods of the service are the tangible aspects of the service that we receive, or are in contact with, during service delivery. In a fine-dining restaurant the physical goods are the food consumed, as well as facilities such as comfortable tables and chairs, tablecloths, and fine china. The sensual benefits are the sights, smell, and sounds of the experience—all the items we experience through our senses. Finally, the psychological benefits include the status, comfort, and well-being provided by the experience.

▶ **Service package**
A grouping of physical, sensual, and psychological benefits that are purchased together as part of the service.

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It is highly important that the design of the service specifically identify every aspect of the service package. When designing the service, we should not focus only on the tangible aspects; it is often the sensual and psychological benefits that are the deciding factors in the success of the service. The service package needs to be designed to precisely meet the expectations of the target customer group.

Once the service package is identified, it can then be translated into a design using a process that is not too different from the one used in manufacturing. Details of the service, such as quality standards and employee training, can later be defined in keeping with the service concept. The service providers—the individuals who come in direct contact with the customers—must be trained and motivated to precisely understand and satisfy customer expectations.

Imagine going to a fast-food restaurant and having the server take his time asking you how you want your hamburger cooked and precisely what condiments you would like to accompany it, then waiting a long time to receive your food. Similarly, imagine going to an expensive hair salon and having the staff rush you through the process. In both cases, you as the customer would not be satisfied because the service delivery did not meet your expectations. Next time you might choose to go somewhere else. These examples illustrate what happens when there is a mismatch between the service concept and the service delivery.

Differing Service Designs

There is no one model of successful service design. The design selected should support the company's service concept and provide the features of the service package that the target customers want. Different service designs have proved successful in different environments. In this section we look at three very different service designs that have worked well for the companies that adopted them.

Substitute Technology for People Substituting technology for people is an approach to service design that was advocated some years ago by Theodore Levitt.[1] Levitt argued that one way to reduce the uncertainty of service delivery is to use technology to develop a production-line approach to services. One of the most successful companies to use this approach is McDonald's. Technology has been substituted wherever possible to provide product consistency and take the guesswork away from employees. Some examples of the use of technology include the following:

- Buzzers and lights are used to signal cooking time for frying perfect french fries.
- The size of the french fryer is designed to produce the correct amount of fries.
- The french fry scoop is the perfect size to fill an order.
- "Raw materials" are received in usable form (e.g., hamburger patties are premade; pickles and tomatoes are presliced; french fries are precut).
- There are 49 steps for producing perfect french fries.
- Steps for producing the perfect hamburger are detailed and specific.
- Products have different-colored wrappings for easy identification.

In addition to the use of technology in the production of the product, there is consistency in facilities and a painstaking focus on cleanliness. For example, the production process at McDonald's is not left to the discretion of the workers. Rather, their job is to follow the technology and preset processes.

Today we are all accustomed to the product consistency, speed of delivery, and predictability that are a feature of most fast-food restaurants. However, this concept was very new in the early 1970s. It is this approach to services that has enabled McDonald's to establish its global reputation.

Substituting technology for people is an approach we have seen over the years in many service industries. For example, almost all gas stations have reduced the number of cashiers and attendants with the advent of credit cards at self-serve pumps. Also, many hospitals are using technology to monitor patient heart rate and blood pressure without relying exclusively on nurses. As technologies develop in different service industries, we will continue to see an ever-increasing reliance on its use and an increase in the elimination of workers.

Get the Customer Involved A different approach to service design was proposed by C. H. Lovelock and R. F. Young.[2] Their idea was to take advantage of the customer's presence during the delivery of the service and have him or her become an active participant. This is different from traditional service designs where the customer passively

[1]Theodore Levitt, "Production Line Approach to Services," *Harvard Business Review*, 50, 5 (September–October 1972), 41–52.

[2]C.H. Lovelock and R.F. Young. "Look to Customers to Increase Productivity," *Harvard Business Review*, 57, 2, 168–178.

Bruce Ayres/Stone/Getty Images Inc.

waits for service employees to deliver the service. Lovelock and Young proposed that since the customers are already there, "get them involved."

We have all seen a large increase in the self-serve areas of many service firms. Traditional salad bars have led to self-serve food buffets of every type. Many fast-food restaurants no longer fill customer drink orders, but have the customers serve themselves. Grocery stores allow customers to select and package baked goods on their own. Many hotels provide in-room coffee makers and prepackaged coffee, allowing customers to make coffee at their convenience.

This type of approach has a number of advantages. First, it takes a large burden away from the service provider. The delivery of the service is made faster, and costs are reduced due to lowered staffing requirements. Second, this approach empowers customers and gives them a greater sense of control in terms of getting what they want, which provides a great deal of customer convenience and increases satisfaction. However, since different types of customers have different preferences, many facilities are finding that it is best to offer full-service and self-service options. For example, many breakfast bars still allow a request for eggs cooked and served to order, and most gas stations still offer some full-service pumps.

High Customer Attention Approach A third approach to service design is providing a high level of customer attention. This is in direct contrast to the first two approaches. The first approach discussed automates the service and makes it more like manufacturing. The second approach requires greater participation and responsibility from the customer. The third approach is different from the first two in that it does not standardize the service and does not get the customer involved. Rather, it is based on customizing the service to the needs unique to each customer and having the customer be the passive and pampered recipient of the service. This approach relies on developing a personal relationship with each customer and giving the customer precisely what he or she wants.

There are a number of examples of this type of approach. Nordstrom, Inc. department stores is recognized in the retail industry for its attention to customer service. Salespeople typically know their customers by name and keep a record of their preferences. Returns are handled without question, and the customer is always right. Another example of this is a midwestern grocer called Dorothy Lane Market. Dorothy Lane prides itself on its ability to provide unique cuts of specialty meats precisely to customer order. As at Nordstrom, a list is kept of primary customers and their preferences. Customers are notified of special purchases, such as unique wines, specialty chocolates, and special cuts of meat.

Whereas the first two approaches to service design result in lowered service costs, this third approach is geared toward customers who are prepared to pay a higher amount for the services they receive. As you can see, different approaches are meant to serve different types of customers. The design chosen needs to support the specific service concept of the company.

PRODUCT DESIGN AND PROCESS SELECTION WITHIN OM: HOW IT ALL FITS TOGETHER

Product design decisions are strategic in nature. The features and characteristics of a product need to support the overall strategic direction of the company. In turn, product design decisions directly dictate the type of process selected. They determine the

types of facilities that will be needed to produce the product, types of machines, worker skills, degree of automation, and other decisions. Most companies continually design new products. The design of these new products has to take into account the type of processes the company has; otherwise facilities may not be available to produce the new product design. Therefore, product design and process selection decisions are directly tied to each other.

Product design and process selection decisions are further linked to all other areas of operations management. They are linked to decisions such as the level of capacity needed (Chapter 9), degree of quality (Chapters 5 and 6), layout (Chapter 10) and location of facilities (Chapter 9), types of workers (Chapter 11), and many others. As we go through this book, we will see how product design and process selection specifically impact other operations decisions.

PRODUCT DESIGN AND PROCESS SELECTION ACROSS THE ORGANIZATION

The strategic and financial impact of product design and process selection mandates that operations work closely with other organizational functions to make these decisions. Operations is an integral part of these decisions because it understands issues of production, ease of fabrication, productivity, and quality. Now let's see how the other organizational functions are involved with product design and process selection.

Marketing is impacted by product design issues because they determine the types of products that will be produced and affect marketing's ability to sell them. Marketing's input is critical at this stage because marketing is the function that interfaces with customers and understands the types of product characteristics customers want. It is marketing that can provide operations with information on customer preferences, competition, and future trends.

Process selection decisions impact marketing as well. They typically require large capital outlays, and once made, they are typically difficult to change and are in place for a long time. Process decisions affect the types of future products that the company can produce. Because of this, marketing needs to be closely involved in ensuring that the process can meet market demands for many years to come.

Finance plays an integral role in product design and process selection issues because these decisions require large financial outlays. Finance needs to be a part of these decisions to evaluate the financial impact on the company. Process selection decisions should be viewed as any other financial investment, with risks and rewards. Finance must ensure that the trade-off between the risks and rewards is acceptable. Also, it is up to finance to provide the capital needed for this investment and to balance that against future capital requirements.

Information systems needs to be part of the process selection decisions. Operations decisions, such as forecasting, purchasing, scheduling, and inventory control, differ based on the type of operation the company has. Information systems will be quite different for intermittent versus continuous operations. Therefore, the information system has to be developed to match the needs of the production process being planned.

Human resources provides important input to process selection decisions because it is the function directly responsible for hiring employees. If special labor skills are needed in the process of production, human resources needs to be able to provide information on the available labor pool. The two types of operations discussed, intermittent and continuous, typically require very different labor skills. Intermittent operations usually require higher-skilled labor than continuous operations. Human resources needs to understand the specific skills that are needed.

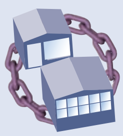
Purchasing works closely with suppliers to get the needed parts and raw materials at a favorable price. It is aware of product and material availability, scarcity, and price. Often certain materials or components can use less expensive substitutes if they are designed properly. For this reason it is important to have purchasing involved in product design issues from the very beginning.

Engineering needs to be an integral part of the product design and process selection decisions because this is the function that understands product measurement, tolerances, strength of materials, and specific equipment needs. There can be many product design ideas, but it is up to engineering to evaluate their manufacturability.

As you can see, product design and process selection issues involve many functions and affect the entire organization. For this reason, product design and process selection decisions need to be made using a team effort, with all these functions working closely together to come up with a product plan that is best for the company.

THE SUPPLY CHAIN LINK

In today's competitive environment, companies typically have a very short window of opportunity to enter the market with a new product design. Most companies are aware that they must get to the market early with an innovative product before their competitors. This requires the support of the entire supply chain, where suppliers must be involved in the product design process. We have already learned about the time-saving advantages of concurrent engineering and early supplier involvement. These require a carefully integrated supply chain that allows collaboration and simultaneous product design between suppliers and manufacturers.



Another important supply chain link relates to the technology decisions the firm makes. As companies acquire new technologies, they must consider how these technologies will be aligned with the technologies used by their supply chain partners. When an entire supply chain uses technologies that are compatible, great strides can be made in the efficiency of production and movement of goods. Consider that Wal-Mart has mandated that its top 300 suppliers must put RFID tags on all their shipping crates and pallets. Although RFID tags are expensive, this move has already incurred huge savings by increasing efficiency, better tracking of products, and a reduction in inventory.

Chapter Highlights

1. Product design is the process of deciding on the unique characteristics and features of a company's product. Process selection, on the other hand, is the development of the process necessary to produce the product being designed. Product design is a big strategic decision for a company, because the design of the product defines who the company's customers will be, as well as the company's image, its competition, and its overall future growth.

2. Steps in product design include idea generation, product screening, preliminary design and testing, and final design. A useful tool at the product-screening stage is break-even analysis.

3. Break-even analysis is a technique used to compute the amount of goods that have to be sold just to cover costs.

4. Production processes can be divided into two broad categories: intermittent and repetitive operations. Intermittent operations are used when products with different characteristics are being produced in smaller volumes. These types of operations tend to organize their resources by grouping similar processes together and having the products routed through the facility based on their needs. Repetitive operations are used when one or a few similar products are produced in high volume. These operations arrange resources in sequence to allow for an efficient buildup of the product. Both intermittent and repetitive operations have their advantages and disadvantages. Intermittent operations provide great flexibility but have high material handling costs and challenge scheduling resources. Repetitive operations are highly efficient but inflexible.

5 Product design and process selection decisions are linked. The type of operation a company has in place is defined by the product the company produces. The type of operation then affects other organizational decisions, such as competitive priorities, facility layout, and degree of vertical integration.

6 A process flowchart is used for viewing the flow of the processes involved in producing the product. It is a very useful tool for seeing the totality of the operation and for identifying potential problem areas. There is no exact format for designing the chart. The flowchart can be very simple or very detailed.

7 Different types of technologies can significantly enhance product and process design. These include automation, automated material handling devices, computer-aided design (CAD), numerically controlled (NC) equipment, flexible manufacturing systems (FMS), and computer-integrated manufacturing (CIM).

8 Designing services have more complexities than manufacturing because services produce an intangible product and typically have a high degree of customer contact. Different service designs include substituting technology for people, getting the customer involved, and paying great attention to the customer.

Key Terms

manufacturability 56
product design 56
service design 57
benchmarking 58
reverse engineering 58
early supplier involvement (ESI) 59
break-even analysis 59
fixed costs 59
variable costs 59
design for manufacture (DFM) 62
product life cycle 63
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radio frequency identification (RFID) 80
automation 80
flexible manufacturing system (FMS) 81
numerically controlled (NC) machine 82
computer-aided design (CAD) 83
computer-integrated manufacturing (CIM) 83
service package 86

Formula Review

1. Total cost = fixed cost + variable cost
2. Revenue = $(SP)Q$
3. $F + (VC)Q = (SP)Q$
4. $Q_{BE} = \dfrac{F}{SP - VC}$
5. Process velocity $= \dfrac{\text{throughput time}}{\text{value-added time}}$
6. Utilization $= \dfrac{\text{time a resource used}}{\text{time a resource available}}$
7. Efficiency $= \dfrac{\text{actual output}}{\text{standard output}}$

Solved Problems

(See student companion site for Excel template.)

• Problem 1

Joe Jenkins, owner of Jenkins Manufacturing, is considering whether to produce a new product. He has considered the operations requirements for the product as well as the market potential. Joe estimates the fixed costs per year to be $40,000 and variable costs for each unit produced to be $50.

(a) If Joe sells the product at a price of $70, how many units of product does he have to sell in order to break even? Use both the algebraic and graphical approaches.

(b) If Joe sells 3000 units at the product price of $70, what will be his contribution to profit?

• *Before You Begin:*

To solve this problem you must first use the break-even formula. Then to compute the contribution to profit, recall that profit is computed as

$$\text{Profit} = \text{total revenue} - \text{total cost}$$

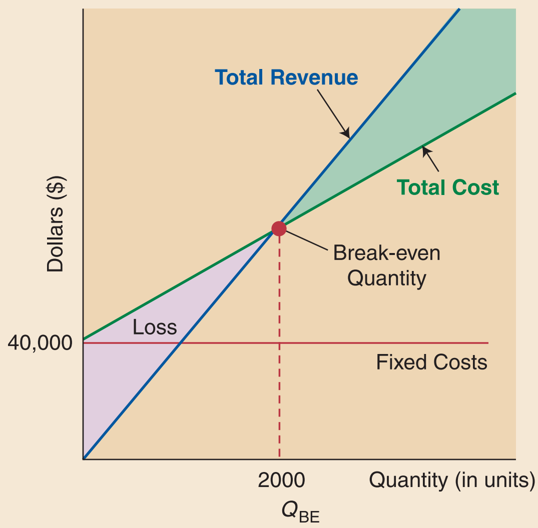
• *Solution:*

(a) To compute the break-even quantity, we follow the equation and substitute the appropriate numerical values:

$$Q = \frac{F}{SP - VC} = \frac{\$40{,}000}{\$70 - \$50} = 2000 \text{ units}$$

The break-even quantity is 2000 units. This is how much Joe would have to sell in order to cover costs.

Graphically, we can obtain the same result. This is shown in the figure.



(b) To compute the contribution to profit with sales of 3000 units:

$$\begin{aligned}\text{Profit} &= \text{total revenue} - \text{total cost}\\ &= (SP)Q - [F + (VC)Q]\end{aligned}$$

Now we can substitute numerical values:

$$\begin{aligned}\text{Profit} &= \$70(3000) - [\$40{,}000 + \$50(3000)]\\ &= \$20{,}000\end{aligned}$$

The contribution to profit is \$20,000 if Joe can sell 3000 units of product.

• Problem 2

Joe Jenkins, owner of Jenkins Manufacturing, has decided to produce the new product discussed in Problem 1. The product can be produced with the current equipment in place. However, Joe is considering the purchase of new equipment that would produce the product more efficiently. Joe's fixed cost would be raised to \$60,000 per year, but the variable cost would be reduced to \$25 per unit. Joe still plans to sell the product at \$70 per unit.

Should Joe produce the new product with the new or current equipment described in Problem 1? Specify the volume of demand for which you would choose each process.

• *Solution*

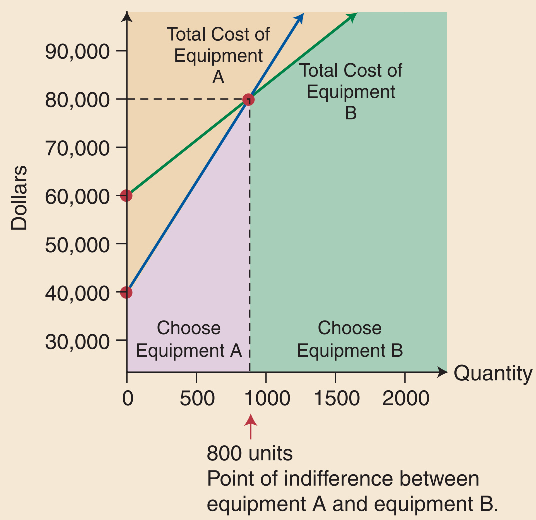
As we mentioned in the chapter, break-even analysis can also be used to evaluate different processes. Here we show how this can be done. To decide which process to use, we first need to compute the point of indifference between the two processes. The point of indifference is where the cost of the two processes is equal. If we label the current equipment A and the new equipment B, the point of indifference occurs when the costs for each process are equal. This is shown as

$$\text{Total cost}_{\text{Equipment A}} = \text{total cost}_{\text{Equipment B}}$$

Again, total cost is the sum of fixed and variable costs:

$$\begin{aligned}\$40{,}000 + \$50\,Q &= \$60{,}000 + \$25\,Q\\ \$25\,Q &= 20{,}000\\ Q &= 800 \text{ units produced}\end{aligned}$$

$Q = 800$ units is the point of indifference, that is, the point where the cost of either equipment is the same. If demand is expected to be less than 800 units, equipment A should be used given that it has a lower fixed cost. If demand is expected to be greater than 800 units, equipment B should be used given that it has a lower variable cost. This is shown graphically.



• Problem 3

Zelle's Dry Cleaners has collected the following data for its processing of dress shirts:

It takes an average of $3\frac{1}{2}$ hours to dry clean and press a dress shirt, with value-added time estimated at 110 minutes per shirt.

Workers are paid for a 7-hour workday and work $5\frac{1}{2}$ hours per day on average, accounting for breaks and lunch; labor utilization is 75 percent in the industry.

The dry cleaner completes 25 shirts per day, with an industry standard of 28 shirts per day for a comparable facility.

Determine process velocity, labor utilization, and efficiency for the company.

• *Before You Begin:*

When solving this problem, remember to keep the units of measure consistent in the numerator and denominator of each equation.

• *Solution*

$$\text{Process velocity} = \frac{\text{throughput time}}{\text{value-added time}}$$

$$= \frac{210 \text{ minutes/shirt}}{110 \text{ minutes/shirt}} = 1.90$$

$$\text{Labor utilization} = \frac{5\frac{1}{2} \text{ hours/day}}{7 \text{ hours/day}} = 0.786 \text{ or } 78.6\%$$

$$\text{Efficiency} = \frac{25 \text{ shirts/day}}{28 \text{ shifts/day}} = 0.89 \text{ or } 89\%$$

Process velocity shows room for process improvement, as throughput time is almost twice that of value-added time. Labor utilization is just above the industry standard, though overall efficiency is below.

Discussion Questions

1. Define product design and explain its relationship to business strategy.
2. What are the differences between product and service design?
3. Explain the meanings of *benchmarking* and *reverse engineering*.
4. Explain the meaning of *design for manufacture (DFM)* and give some examples.
5. Describe the stages of the product life cycle. What are demand characteristics at each stage?
6. Explain the term *concurrent engineering*. Why is it important?
7. Identify the two general types of operations. What are their characteristics?
8. What is meant by the term *vertical integration*? What types of companies are more likely to become vertically integrated?
9. What is a process flowchart, and what is it used for?
10. Give some examples of automation. How has automation changed the production process?
11. Discuss the benefits of computer-aided design (CAD).
12. What is meant by the term *service package*?
13. Name three service companies and describe their service package.
14. Give examples of services that have a good match between customer expectations and service delivery. Give examples of services that do not have a good match.

Problems

1. See-Clear Optics is considering producing a new line of eyewear. After considering the costs of raw materials and the cost of some new equipment, the company estimates fixed costs to be $40,000 with a variable cost of $45 per unit produced.
   (a) If the selling price of each new product is set at $100, how many units need to be produced and sold to break even? Use both the graphical and algebraic approaches.
   (b) If the selling price of the product is set at $80 per unit, See-Clear expects to sell 2000 units. What would be the total contribution to profit from this product at this price?
   (c) See-Clear estimates that if it offers the product at the original target price of $100 per unit, the company will sell about 1500 units. Will the pricing strategy of $100 per unit or $80 per unit yield a higher contribution to profit?

2. Med-First is a medical facility that offers outpatient medical services. The facility is considering offering an additional service, mammography screening tests, on-site. The facility estimates the annual fixed cost of the equipment and skills necessary for the service to be $120,000. Variable costs for each patient processed are estimated at $35 per patient. If the clinic plans to charge $55 for each screening test, how many patients must it process a year in order to break even?

3. Tasty Ice Cream is a year-round take-out ice cream restaurant that is considering offering an additional product, hot chocolate. Considering the additional machine it would need plus cups and ingredients, it estimates fixed costs to be $200 per year and the variable cost to be $0.20. If it charges $1.00 for each hot chocolate, how many hot chocolates does it need to sell in order to break even?

4. Slick Pads is a company that manufactures laptop notebook computers. The company is considering adding its own line of computer printers as well. It has considered the implications from the marketing and financial perspectives and estimates fixed costs to be $500,000. Variable costs are estimated at $200 per unit produced and sold.

(a) If the company plans to offer the new printers at a price of $350, how many printers does it have to sell to break even?
(b) Describe the types of operations considerations that the company needs to consider before making the final decision.

5. Perfect Furniture is a manufacturer of kitchen tables and chairs. The company is currently deciding between two new methods for making kitchen tables. The first process is estimated to have a fixed cost of $80,000 and a variable cost of $75 per unit. The second process is estimated to have a fixed cost of $100,000 and a variable cost of $60 per unit.

(a) Graphically plot the total costs for both methods. Identify which ranges of product volume are best for each method.
(b) If the company produces 500 tables a year, which method provides a lower total cost?

6. Harrison Hotels is considering adding a spa to its current facility in order to improve its list of amenities. Operating the spa would require a fixed cost of $25,000 a year. Variable cost is estimated at $35 per customer. The hotel wants to break even if 12,000 customers use the spa facility. What should be the price of the spa services?

7. Kaizer Plastics produces a variety of plastic items for packaging and distribution. One item, container #145, has had a low contribution to profits. Last year, 20,000 units of container #145 were produced and sold. The selling price of the container was $20 per unit, with a variable cost of $18 per unit and a fixed cost of $70,000 per year.

(a) What is the break-even quantity for this product? Use both graphic and algebraic methods to get your answer.
(b) The company is currently considering ways to improve profitability by either stimulating sales volumes or reducing variable costs. Management believes that sales can be increased by 35 percent of their current level or that variable cost can be reduced to 90 percent of their current level. Assuming all other costs equal, identify which alternative would lead to a higher profit contribution.

8. George Fine, owner of Fine Manufacturing, is considering the introduction of a new product line. George has considered factors such as costs of raw materials, new equipment, and requirements of a new production process. He estimates that the variable costs of each unit produced would be $8 and fixed costs would be $70,000.

(a) If the selling price is set at $20 each, how many units have to be produced and sold for Fine Manufacturing to break even? Use both graphical and algebraic approaches.
(b) If the selling price of the product is set at $18 per unit, Fine Manufacturing expects to sell 15,000 units. What would be the total contribution to profit from this product at this price?
(c) Fine Manufacturing estimates that if it offers the product at the original target price of $20 per unit, the company will sell about 12,000 units. Which pricing strategy—$18 per unit or $20 per unit—will yield a higher contribution to profit?
(d) Identify additional factors that George Fine should consider in deciding whether to produce and sell the new product.

9. Handy-Maid Cleaning Service is considering offering an additional line of services to include professional office cleaning. Annual fixed costs for this additional service are estimated to be $9000. Variable costs are estimated at $50 per unit of service. If the price of the new service is set at $80 per unit of service, how many units of service are needed for Handy-Maid to break even?

10. Easy-Tech Software Corporation is evaluating the production of a new software product to compete with the popular word processing software currently available. Annual fixed costs of producing the item are estimated at $150,000, and the variable cost is $10 per unit. The current selling price of the item is $35 per unit, and the annual sales volume is estimated at 50,000 units.

(a) Easy-Tech is considering adding new equipment that would improve software quality. The negative aspect of this new equipment would be an increase in both fixed and variable costs. Annual fixed costs would increase by $50,000 and variable costs by $3. However, marketing expects the better-quality product to increase demand to 70,000 units. Should Easy-Tech purchase this new equipment and keep the price of their product the same? Explain your reasoning.
(b) Another option being considered by Easy-Tech is the increase in the selling price to $40 per unit to offset the additional equipment costs. However, this increase would result in a decrease in demand to 40,000 units. Should Easy-Tech increase its selling price if it purchases the new equipment? Explain your reasoning.

11. Zodiac Furniture is considering the production of a new line of metal office chairs. The chairs can be produced in-house using either process A or process B. The chairs can also be purchased from an outside supplier. Specify the levels of demand for each processing alternative given the costs in the table.

	Fixed Cost	Variable Cost
Process A	$20,000	$30
Process B	$30,000	$15
Outside Supplier	$0	$50

12. Mop and Broom Manufacturing is evaluating whether to produce a new type of mop. The company is considering the operations requirements for the mop as well as the market potential. Estimates of fixed costs per year are $40,000, and the variable cost for each mop produced is $20.

(a) If the company sells the product at a price of $25, how many units of product have to be sold in order to break even? Use both the algebraic and graphical approaches.
(b) If the company sells 10,000 mops at the product price of $25, what will be the contribution to profit?

13. Mop and Broom Manufacturing, from Problem 12, has decided to produce a new type of mop. The mop can be made with the current equipment in place. However, the company is considering the purchase of new equipment that would produce

the mop more efficiently. The fixed cost would be raised to $50,000 per year, but the variable cost would be reduced to $15 per unit. The company still plans to sell the mops at $25 per unit. Should Mop and Broom produce the mop with the new or current equipment described in Problem 12? Specify the volume of demand for which you would choose each process.

14. Jacob's Baby Food Company must go through the following steps to make mashed carrots: (1) unload carrots from truck; (2) inspect carrots; (3) weigh carrots; (4) move to storage; (5) wait until needed; (6) move to washer; (7) boil in water; (8) mash carrots; (9) inspect. Draw a process flow diagram for these steps.

15. Draw a process flow diagram of your last doctor's office visit. Identify bottlenecks. Did any activities occur in parallel?

16. Oakwood Outpatient Clinic is analyzing its operation in an effort to improve performance. The clinic estimates that a patient spends on average $3\frac{1}{2}$ hours at the facility. The amount of time the patient is in contact with staff (i.e., physicians, nurses, office staff, lab technicians) is estimated at 40 minutes. On average the facility sees 42 patients per day. Their standard has been 40 patients per day. Determine process velocity and efficiency for the clinic.

17. Oakwood Outpatient Clinic rents a magnetic resonance imaging (MRI) machine for 30 hours a month for use on its patients. Last month the machine was used 28 hours out of the month. What was machine utilization?

18. Mop and Broom Manufacturing estimates that it takes $4\frac{1}{2}$ hours for each broom to be produced, from raw materials to final product. An evaluation of the process reveals that the amount of time spent working on the product is 3 hours. Determine process velocity.

CASE: Biddy's Bakery (BB)

Biddy's Bakery was founded by Elizabeth McDoogle in 1984. Nicknamed "Biddy," Elizabeth started the home-style bakery in Cincinnati, Ohio, as an alternative to commercially available baked goods. The mission of Biddy's Bakery was to produce a variety of baked goods with old-fashioned style and taste. The goods produced included a variety of pies and cakes and were sold to the general public and local restaurants.

The operation was initially started as a hobby by Elizabeth and a group of her friends. Many of the recipes they used had been passed down for generations in their families. The small production and sales facility was housed in a mixed commercial and residential area on the first floor of "Biddy's" home. Elizabeth ("Biddy") and three of her friends worked in the facility from 6 a.m. to 2 p.m. making and selling the pies. The operation was arranged as a job shop with workstations set up to perform a variety of tasks as needed. Most of the customers placed advanced orders, and Biddy's Bakery took pride in accepting special requests. The bakery's specialty was the McDoogle pie, a rich chocolate confection in a cookie crust.

Meeting Capacity Needs

Initially sales were slow, and there were periods when the business operated at a loss. However, after a few years Biddy's Bakery began to attract a loyal customer following. Sales continued to grow slowly but steadily. In 1994 a first floor storage area was expanded to accommodate the growing business. However, Biddy's Bakery quickly outgrew its current capacity. In May of 2000 Elizabeth decided to purchase the adjacent building and move the entire operation into the much larger facility. The new facility had considerably more capacity than needed, but the expectation was that business would continue to grow. Unfortunately, by the end of 2000 Elizabeth found that her sales expectations had not been met, and she was paying for a facility with unused space.

Getting Management Advice

Elizabeth knew that her operations methods, though traditional, were sound. A few years ago she had called upon a team of business students from a local university for advice as part of their course project. They had offered some suggestions but were most impressed with the efficient manner with which she ran her operation. Recalling this experience, she decided to contact the same university for another team of business students to help her with her predicament.

After considerable analysis the team of business students came up with their plan: Biddy's Bakery should primarily focus on production of the McDoogle pie in large volumes, with major sales to go to a local grocery store. The team of business students discussed this option with a local grocery store chain that was pleased with the prospect. Under the agreement Biddy's Bakery would focus its production on the McDoogle pie, which would be delivered in set quantities to one store location twice a week. The volume of pies required would use up all of the current excess capacity and take away most of the capacity from production of other pies.

Elizabeth was confused. The alternative being offered would solve her capacity problems, but it seemed that the business would be completely different, though she did not understand how or why. For the first time in managing her business she did not know what to do.

Case Questions

1. Explain the challenge Elizabeth faced in meeting her capacity needs. What should she have considered before moving into the larger facility?

2. What is wrong with the proposal made by the team of business students? Why?

3. What type of operation does Biddy's Bakery currently have in place? What type of operation is needed to meet the proposal made by the team of business students? Explain the differences between these two operations.

4. Elizabeth senses that the business would be different if she accepts the proposal but does not know how and why. Explain how it would be different.

5. What would you advise Elizabeth?

CASE: Creature Care Animal Clinic (B)

Company Background

Creature Care Animal Clinic is a suburban veterinary clinic specializing in the medical care of dogs and cats. Dr. Julia Barr opened the clinic three years ago, hiring another full-time veterinarian, a staff of three nurses, an office manager, and an office assistant. The clinic operates Monday through Friday during regular business hours, with half days on Saturdays and extended hours on Wednesday evenings. Both doctors work during the week and take turns covering Wednesday evenings and Saturdays.

Dr. Barr opened the clinic with the intent of providing outpatient animal care. Overnight services are provided for surgical patients only. No other specialized services are offered. The facility for the clinic was designed for this type of service, with a spacious waiting and reception area. The examining and surgical rooms are in the rear, just large enough to accommodate their initial purpose.

As time has passed, however, the number of patients requesting specialized services has increased. Initially the requests were few, so Dr. Barr tried to accommodate them. As one of the nurses was also trained in grooming services, she began to alternate between her regular duties and pet grooming. Pet grooming was performed in the rear of the reception area, as it was spacious and there was no other room for this job. At first this was not a problem. However, as the number of pets being groomed increased, the flow of work began to be interrupted. Customers waiting with their pets would comment to the groomer in the rear, who had difficulty focusing on the work. The receptionist was also distracted, as were the animals.

The number of customers requesting grooming services was growing rapidly. Customers wanted to drop off their pets for a "package" of examining, grooming, and even minor surgical procedures requiring overnight stays. The space for grooming and overnight services was rapidly taking over room for other tasks. Also, most of the staff was not trained in providing the type of service customers were now requiring.

The Dilemma

Dr. Barr sat at her desk wondering how to handle the operations dilemma she was faced with. She started her business as a medical clinic but found that she was no longer sure what business she was in. She didn't understand why it was so complicated given that she was only providing a service. She was not sure what to do.

Case Questions

1. Identify the operations management problems that Dr. Barr is having at the clinic.
2. How would you define the "service bundle" currently being offered? How is this different from the initial purpose of the clinic?
3. Identify the high-contact and low-contact segments of the operation. How should each be managed?
4. What should Dr. Barr have done differently to avoid the problems she is currently experiencing? What should Dr. Barr do now?

INTERACTIVE CASE Virtual Company

www.wiley.com/college/reid

On-line Case: Cruise International, Inc.

Assignment: *Service Package and Processes at Cruise International, Inc.* Now that you have learned something about the big picture at CII, you believe it is time to learn some specifics. You call Bob Bristol to report your progress and ask for the details of your next assignment.

"I am pleased with your progress in familiarizing yourself with CII and its operations. Now it is time for you to tackle a specific assignment under the direction of Leila Jensen, the hotel manager aboard the MS *Friendly Dreams* I. Specifically, you must develop a good understanding of the service package currently offered by CII to its customers and the service delivery process it uses. At the strategic level, the service package must be consistent with the company's mission statement and the competitive priorities that it wants to emphasize." This assignment will enhance your knowledge of the material in Chapter 3 of your textbook while preparing you for future assignments.

To access the Web site:

- Go to **www.wiley.com/college/reid**
- Click **Student Companion Site**
- Click **Virtual Company**
- Click **Consulting Assignments**
- Click **Service Package and Processes at CII**

INTERNET CHALLENGE Country Comfort Furniture

You have just taken a position with Country Comfort Furniture, a furniture manufacturer known for its custom-designed country furniture. The primary focus of the company has been on kitchen and dining room furniture in the upper portion of the high-price range. Due to competitive pressures and changes in the market, Country Comfort is now considering production of prefabricated kitchen and dining room furniture in the medium-price range.

You have been asked to help Country Comfort evaluate the new product design it is considering. Perform an Internet search to identify at least two major competitors that Country Comfort would have if it chooses to pursue the new product line. Next, identify key product design features of each competitor's products, their target market, and price range. Based on your search, what are your recommendations to Country Comfort on product design and current competition?

On-line Resources

WILEY PLUS

Companion Website www.wiley.com/college/reid

- Take interactive *practice quizzes* to assess your knowledge and help you study in a dynamic way
- Review *PowerPoint slides* or print slides for notetaking
- Download *Excel Templates* to use for problem solving
- Access the *Virtual Company: Cruise International, Inc.*
- Find links to *Company Tours* for this chapter
  Ercol Furniture Ltd.
- Find links for *Additional Web Resources* for this chapter
  Institute for Supply Chain Management, *www.ism.ws*

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CHAPTER 4

Supply Chain Management

Before studying this chapter you should know or, if necessary, review

1. The implications of competitive priorities, Chapter 2, pp. 36–39.
2. Product design considerations, Chapter 3, pp. 57–65.
3. Process selection considerations, Chapter 3, pp. 65–69.

LEARNING OBJECTIVES

After studying this chapter you should be able to

1. Describe the structure of supply chains.
2. Describe the bullwhip effect.
3. Describe supply chains for service organizations.
4. Describe major issues affecting supply chains.
5. Describe electronic commerce.
6. Describe global issues affecting supply chains.
7. Describe government regulation issues affecting supply chains.
8. Describe green supply chain management.
9. Describe the role of purchasing in supply chain management.
10. Describe sourcing issues.
11. Describe strategic purchasing partnerships.
12. Describe ethics in supplier management.
13. Describe supply chain distribution.
14. Describe how to implement supply chain management.
15. Describe supply chain management metrics.
16. Describe trends in supply chain management.

CHAPTER OUTLINE

WHAT'S IN OM FOR ME?

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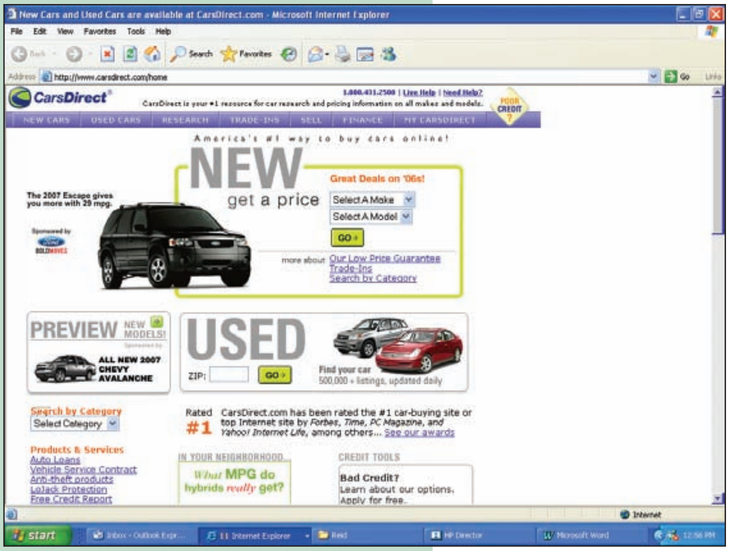
Buying a product used to mean browsing through mail-order catalogs or getting dressed, leaving home, and shopping at stores or malls until you found what you wanted. Today, most of us can go on-line anytime during the day, seven days a week, and buy just about anything over the Internet. You can shop while sitting at your computer and never need to leave home. You can order food from a supermarket or a restaurant on-line or buy clothing and household goods. You can buy books, videos, CDs, or more expensive products like diamonds and cars, or even book your vacation—the Internet has revolutionized the way we do business by allowing us access to numerous suppliers around the world.



Courtesy Cars Direct

The Internet also has allowed companies to change the way they find the materials and supplies that are needed for their operations. Business-to-business (B2B) transactions are conducted between companies and their suppliers, distributors, and customers. Even though direct sales to the general public are more familiar, B2B transactions make up the majority of Internet transactions.

One of the most publicized examples is Covisint, a global business-to-business automotive supplier exchange site, begun in 2000 as an initiative by the U.S. automakers Ford Motor Company, General Motors, DaimlerChrysler, Nissan/Renault, and PSA Peugeot Citroën. Covisint became the largest industry-sponsored net marketplace. Covisint has over 300,000 users, representing 45,000 different companies, located in 96 different countries. Covisint is the electronic marketplace for the auto industry, providing on-line purchasing services and promoting supply chain collaboration between major direct suppliers and automakers.

WHAT IS A SUPPLY CHAIN?

A **supply chain** is the network of activities that delivers a finished product or service to the customer. These include sourcing raw materials and parts, manufacturing and assembling the products, warehousing, order entry and tracking, distribution through the channels, and delivery to the customer. An organization's supply chain is facilitated by an information system that allows relevant information such as sales data, sales forecasts, and promotions to be shared among members of the supply chain. Figure 4-1 shows a basic supply chain structure for a manufacturer.

▶ **Supply chain**
A network of all the activities involved in delivering a finished product or service to the customer.

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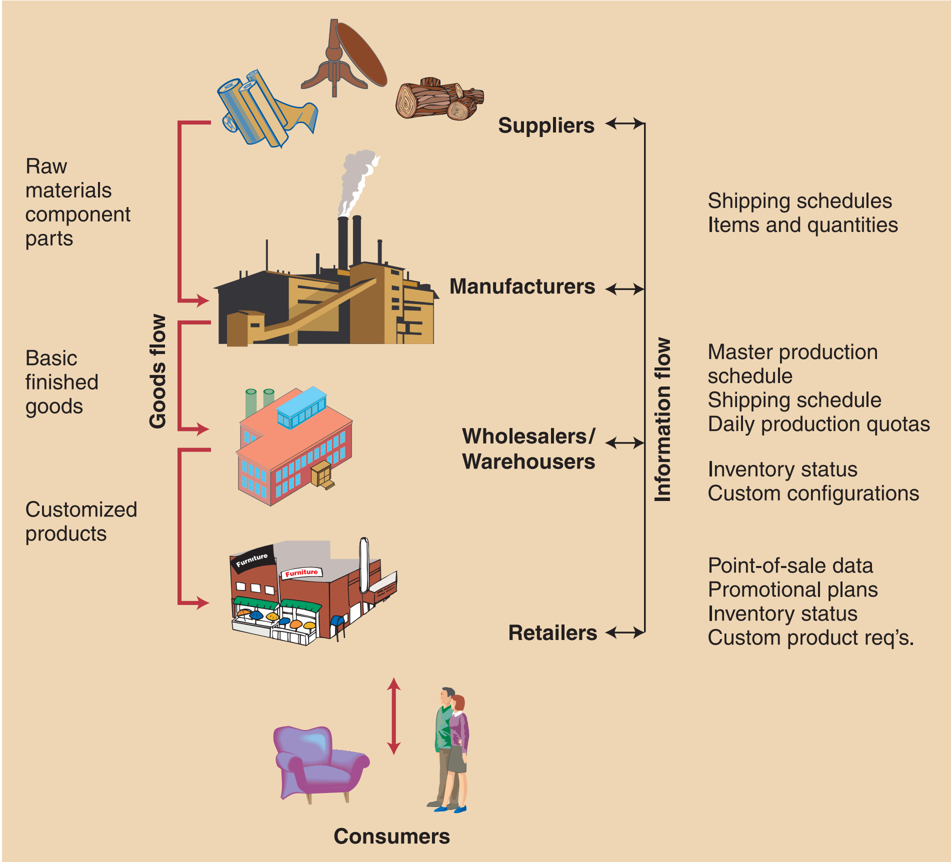
At the beginning of the chain are the external suppliers who supply and transport raw materials and components to the manufacturers. Manufacturers transform these materials into finished products that are shipped either to the manufacturer's own distribution centers or to wholesalers. Next, the product is shipped to retailers who sell the product to the customer. Goods flow from the beginning of the chain through the

FIGURE 4-1

Basic supply chain



manufacturing process to the customer. Relevant information flows back and forth among members of the supply chain.

▶ **Supply chain management** Coordinates and manages all the activities of the supply chain.

Supply chain management is the vital business function that coordinates and manages all the activities of the supply chain linking suppliers, transporters, internal departments, third-party companies, and information systems. Supply chain management for manufacturers entails

- Coordinating the movement of goods through the supply chain from suppliers to manufacturers to distributors to the final customers
- Sharing relevant information such as sales forecasts, sales data, and promotional campaigns among members of the chain

A prime example of operations management (OM), supply chain management provides the company with a sustainable, competitive advantage, such as quick response time, low cost, state-of-the-art quality design, or operational flexibility.

Dell Computer Corporation is a good example of a company using its supply chain to achieve a sustainable competitive advantage. Quick delivery of customized computers at prices 10–15 percent lower than the industry standard is Dell's competitive advantage. A customized Dell computer can be en route to the customer within 36 hours. This quick response allows Dell to reduce its inventory level to approximately 13 days of supply compared to Compaq's 25 days of supply. Dell achieves this in part through its warehousing plan. Most of the components Dell uses are warehoused within 15 minutes travel time to an assembly plant. Dell does not order components at its Austin, Texas, facility; instead, suppliers restock

warehouses as needed, and Dell is billed for items only after they are shipped. The result is better value for the customer.

COMPONENTS OF A SUPPLY CHAIN FOR A MANUFACTURER

A company's supply chain structure has three components: external suppliers, internal functions of the company, and external distributors. Figure 4-2 shows a simplified supply chain for packaged dairy products.

External suppliers include the dairy farmer, cardboard container manufacturer, label company, plastic container manufacturer, paper mill, chemical processing plant, lumber company, and chemical extraction plant. Internal functions include the processing of the raw milk into consumer dairy products and packaging and labeling dairy products for

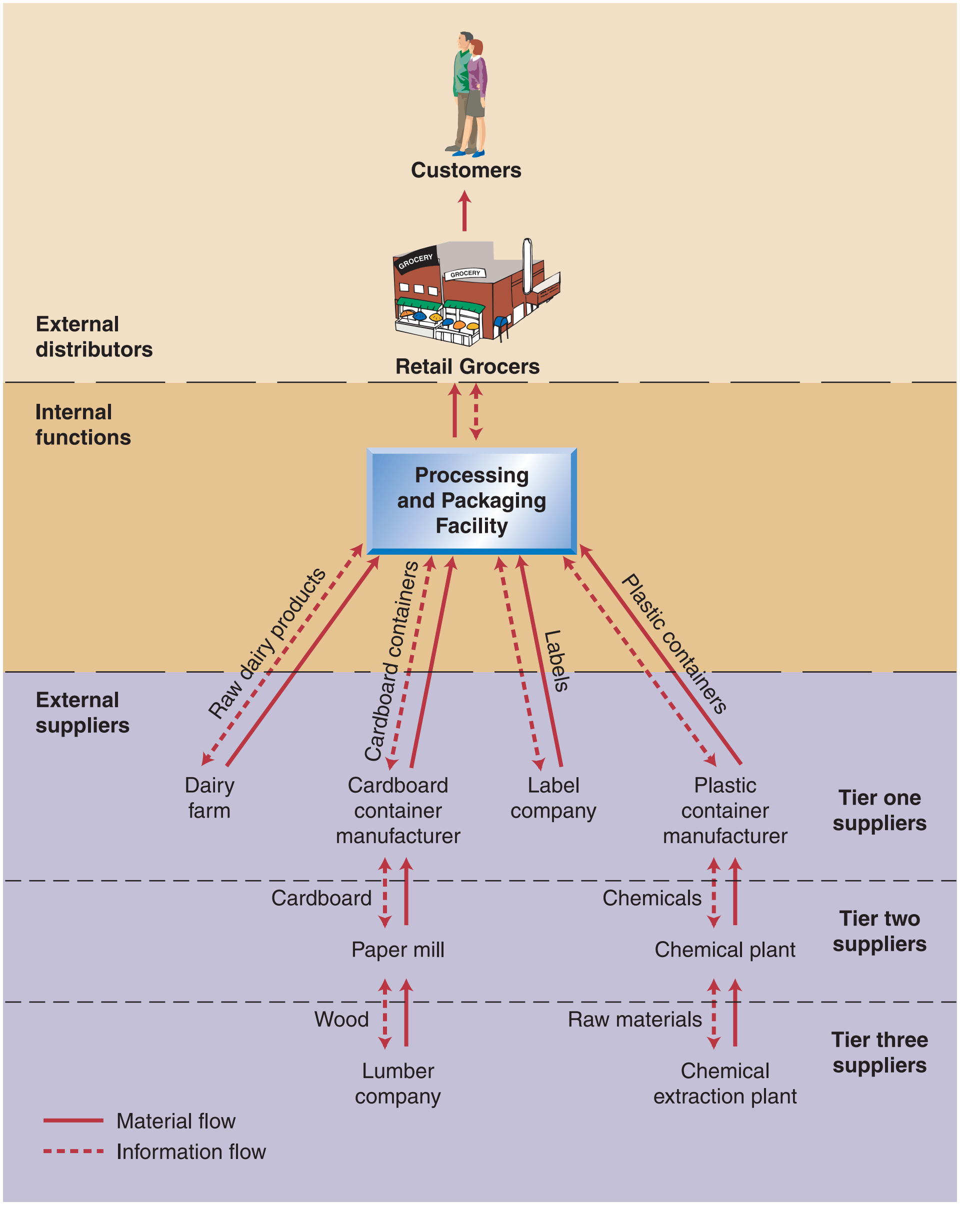


FIGURE 4-2

Dairy products supply chain

distribution to retail grocery outlets. The external distributors transport finished products from the manufacturer to retail grocers, where the products are sold to the customer. The supply chain includes every activity from collecting the raw milk, producing the consumer dairy products, packaging the dairy products, distributing the packaged dairy products to retail grocers, to selling the finished dairy products to the customer.

Let's look at each component of the supply chain in detail.

External Suppliers

Dairy products manufacturing involves several companies, as shown in Figure 4-2. The dairy products are packaged either in cardboard or plastic containers made by **tier one suppliers**. Note that any supplier that provides materials directly to the processing facility is designated as a tier one supplier (in this case, the dairy farm, the cardboard container manufacturer, the label company, and the plastic container manufacturer).

▶ **Tier one supplier** Supplies materials or services directly to the processing facility.

▶ **Tier two supplier** Directly supplies materials or services to a tier one supplier in the supply chain.

▶ **Tier three supplier** Directly supplies materials or services to a tier two supplier in the supply chain.

The paper mill and the chemical processing plant are **tier two suppliers** because they directly supply tier one suppliers but do not directly supply the packaging operation. The lumber company that provides wood to the paper mill is a **tier three supplier**, as is the chemical extraction plant that supplies raw materials to the chemical processing plant.

Companies put substantial effort into developing the external supplier portion of the supply chain because the cost of materials might represent 50–60 percent or even more of the cost of goods sold. A company is typically involved in a number of supply chains and often in different roles. In the supply chain for the plastics container manufacturer shown in Figure 4-2, for example, the chemical plant is now a tier one supplier and the chemical extraction facility is a tier two supplier. Even though the plastics container manufacturer was a tier one supplier to the milk processing facility, the plastic container manufacturer still has its own unique supply chain. Now consider the supply chain for a retail grocer: the tier one suppliers are providers of packaged consumer products, and the grocer has no external distributors because the customers buy directly from the store. As you can see, supply chains come in all shapes and sizes.

Remember that tier one suppliers (the cardboard container manufacturer, dairy farm, label company, and plastics container manufacturer in Figure 4-2) directly supply the consumer product manufacturer (packaged dairy products), whereas tier two suppliers (paper mill and chemical processing plant) directly supply tier one suppliers. To summarize: supply chains are a series of linked suppliers and customers in which each customer is a supplier to another part of the chain until the product is delivered to the final customer.

Internal Functions

Internal functions in, for example, a dairy products supply chain are as follows:

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- Processing, which converts raw milk into dairy products and packages these products for distribution to retail grocery outlets.
- Purchasing, which selects appropriate suppliers, ensures that suppliers perform up to expectations, administers contracts, and develops and maintains good supplier relationships.
- Production planning and control, which schedules the processing of raw milk into dairy products.
- Quality assurance, which oversees the quality of the dairy products.
- Shipping, which selects external carriers and/or a private fleet to transport the product from the manufacturer facility to its destination.

External Distributors

External distributors transport finished products to the appropriate locations for eventual sale to customers. Logistics managers are responsible for managing the movement of products between locations. **Logistics** includes *traffic management* and *distribution management*. **Traffic management** is the selection and monitoring of external carriers (trucking companies, airlines, railroads, shipping companies, and couriers) or internal fleets of carriers. **Distribution management** is the packaging, storing, and handling of products at receiving docks, warehouses, and retail outlets.

Next, we will look at a common challenge to supply chain managers called the bullwhip effect.

▶ **Logistics**
Activities involved in obtaining, producing, and distributing materials and products in the proper place and in proper quantities.

▶ **Traffic management**
Responsible for arranging the method of shipment for both incoming and outgoing products or materials.

▶ **Distribution management**
Responsible for movement of material from the manufacturer to the customer.

THE BULLWHIP EFFECT

Sharing product demand information between members of a supply chain is critical. However, inaccurate or distorted information can travel through the chain like a bullwhip uncoiling. The **bullwhip effect**, as this is called, causes erratic replenishment orders placed on different levels in the supply chain that have no apparent link to final product demand. The results are excessive inventory investment, poor customer service levels, ineffective transportation use, misused manufacturing capacity, and lost revenues. We will discuss the causes of the bullwhip effect, and how they send inaccurate or distorted information down the supply chain. First, however, let's look at the traditional supply chain, shown in Figure 4-3, and follow the product demand information flow from the final seller back to the manufacturer of the product:

▶ **Bullwhip effect**
Inaccurate or distorted demand information created in the supply chain.

1. The final seller periodically places replenishment orders with the next level of the supply chain, which could be a local distributor. The timing and order quantity—for example, monthly orders in varying amounts—are determined by the final seller. The timing and quantity can be fixed or variable.
2. The local distributor has many customers (final sellers) placing replenishment orders. Each final seller uses it own product demand estimates and quantity

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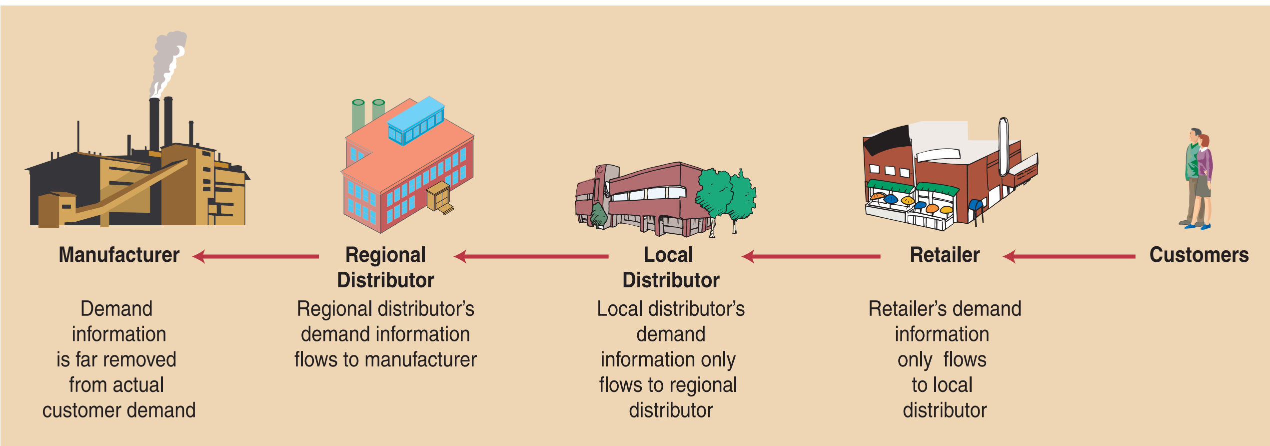
FIGURE 4-3

Traditional supply chain information flow



rules. Based on these replenishment orders, the local distributor places replenishment orders with its supplier, which could be a regional distribution center (RDC).

3. As before, the customers (the local distributors) determine the timing and quantity of orders placed with the RDC. Each RDC periodically places orders based on demand at the RDC by ordering from the manufacturer of the finished good.
4. In turn, the manufacturer develops plans and schedules production orders based on orders from the RDCs. The manufacturer does not know what the demand is for the finished good by the final customer but knows only what the RDCs order.

The greater the number of levels in the supply chain, the further away the manufacturer is from final customer demand. Since suppliers in the chain do not know what customer demand is or when a replenishment order might arrive, suppliers stockpile inventory.

Causes of the Bullwhip Effect

The causes of the bullwhip effect are demand forecast updating, order batching, price fluctuation, and rationing and gaming. Let's look at each of these causes.

Each member in the supply chain, beginning with the retailers, does *demand forecast updating* with every inventory review. Based on actual demand, the retailers update their demand forecast. The retailers review their current inventory level and, based on their inventory policies, determine whether a replenishment order is needed. The wholesalers repeat the process. Note that the demand is from the retailers' inventory replenishments and may not reflect actual customer demand at the retail level. The wholesalers update their demand forecast and place appropriate replenishment orders with the distribution centers. The distributors repeat the process, updating their demand forecasts based on demand from the wholesalers. The distributors review their inventory levels and place the appropriate orders with the manufacturer. These orders are determined by the inventory policies at the distributors. Orders placed with the manufacturer end up replenishing each level in the supply chain rather than being directly linked to end-customer demand.

A company does *order batching* when, instead of placing replenishment orders right after each unit is sold, it waits some period of time, sums up the number of units sold, and then places the order. This changes constant product demand to lumpy demand—a situation where certain levels in the supply chain experience periods of no demand. Order batching policies amplify variability in order timing and size.

Price fluctuations cause companies to buy products before they need them. Price fluctuations follow special promotions like price discounts, quantity discounts, coupons, and rebates. Each of these price fluctuations affects the replenishment orders placed in the supply system. When prices are lower, members of the supply chain tend to buy in larger quantities. When prices increase, order quantities decrease. Price fluctuations create more demand variability within the supply chain.

Rationing and shortage gaming result when demand exceeds supply and products are rationed to members of the supply chain. Knowing that the manufacturer will ration items, customers within the supply chain often exaggerate their needs. For example, if you know the company is supplying only 50 percent of the order quantity, you double the order size. If you really need 100 pieces, you order 200 so you are sure to get what you need. Such game-playing distorts true demand information in the system.

Counteracting the Bullwhip Effect

Here are four ways of counteracting the bullwhip effect:

1. Change the way suppliers forecast product demand by making this information from the final-seller level available to all levels of the supply chain. This allows all levels to use the same product demand information when making replenishment decisions. Companies can do this by collecting point-of-sale (POS) information, a function available on most cash registers.
2. Eliminate order batching. Companies typically use large order batches because of the relatively high cost of placing an order. Supply chain partners can reduce ordering costs by using electronic data interchange (EDI) to transmit information. Lower ordering costs eliminate the need for batch orders.
3. Stabilize prices. Manufacturers can eliminate incentives for retail forward buying by creating a uniform wholesale pricing policy. In the grocery industry, for example, major manufacturers use an everyday low-price policy or a value-pricing strategy to discourage forward buying.
4. Eliminate gaming. Instead of filling an order based on a set percentage, manufacturers can allocate products in proportion to past sales records. Customers then have no incentive to order a larger quantity to get the quantity they need.

SUPPLY CHAINS FOR SERVICE ORGANIZATIONS

Up till now, the discussion has focused on supply chains for manufacturing organizations rather than supply organizations. However, service organizations can also benefit from supply chain management. A supply chain for a service organization is similar to that for manufacturing organizations since external suppliers, internal operations, and external distributors can be needed. In the case of an e-tailer, supply chain management can be used to integrate external suppliers (usually providing better demand forecast information to its suppliers, thus reducing uncertainty within the chain); it has internal operations with regard to order processing, order picking, and so on; and it can have external distribution done by a third-party provider (such as FedEx, UPS, or DHL).

Let's look at an example of a supply chain for a full-service travel agency as shown in Figure 4-4. The agency arranges a wide variety of trips for its customers. The service

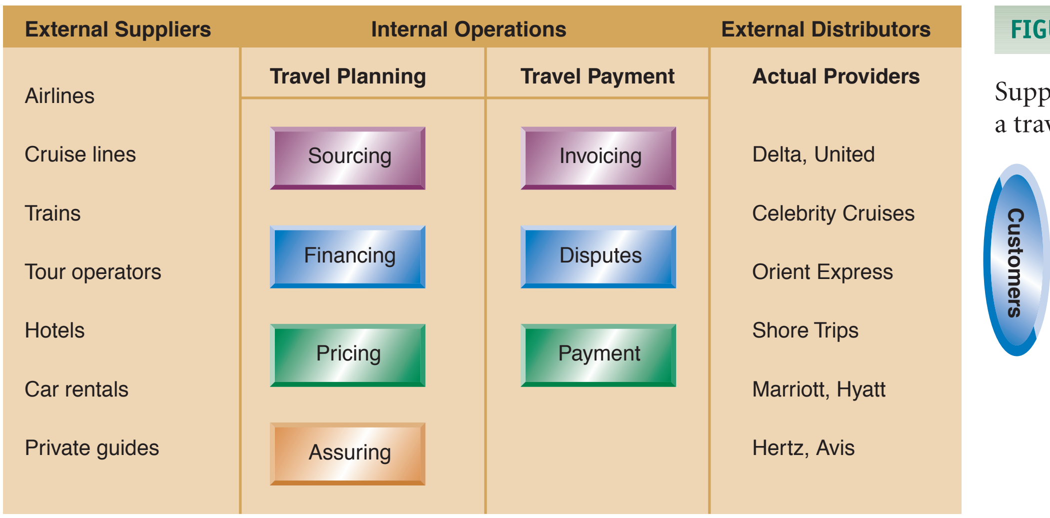


FIGURE 4-4

Supply chain for a travel agency

can be as simple as making airline, train, hotel, cruise, car rental, or personal tour arrangements for the customer. A customer can require a single type of service or have a highly complicated travel request.

Internal Operations

The internal operations at the travel agency are split into two parts: Travel Enablement and Travel Billing.

Travel Enablement begins with qualifying potential suppliers of travel services. The agency does not provide the actual travel but makes the arrangements. The agency must know the scope of services provided, as well as the quality of the services, the reliability of the provider, the safety of the service, the financial solvency, the language capability of the provider, and the like. As people travel throughout the world, it is critical to qualify any service providers used by the agency. The better the agency develops its external suppliers, the better it can match its customers with the right service providers.

The next step deals with the different forms of credit since no business transaction is completed without assuring the financing first. Providers in many developing nations don't accept credit cards for payment, so it may be necessary to arrange bank transfers (possibly in the local currency) to finalize the service commitment. The agency must also clarify refund and cancellation policies.

Pricing deals with negotiation of terms for delivery of the service and price discounts. Group discounts may be available. Discounts may be offered for services booked during traditionally low seasons. The agency can use integrated cost data, including available discounts and other incentives, to influence customer decisions.

The last process of Travel Enablement is assuring that any risk is minimized for the customer. This can be done by having integrated supplier performance files. The agency can evaluate past performance by the supplier and determine how to minimize any risk associated with using the supplier (a backup provider, just in case) or travel insurance.

Travel Enablement is about having a database of service providers that can be accessed instantly for use in arranging real-time travel for customers. Often the customer is sitting at the desk of a travel agent or is on the phone or Internet with the agent. The integrated database facilitates travel arrangements.

Travel Billing includes invoicing, dispute resolution, and payment to suppliers. The agency creates an integrated invoice for its customers. The agency can have both commercial and private accounts. Commercial clients can often receive a consolidated invoice monthly. Most private accounts are invoiced after the trip has been booked. It can include a payment required at time of booking, with the balance due prior to the actual travel. Providing a consolidated invoice reduces the number of transactions with the customer. Often systems for electronic payment are used.

The agency can be the focal point for all complaint resolution. This reduces the risk of miscommunications and provides a resolution process for both the customer and the service provider.

Payment of the invoice to the agency results in subsequent payment to the service providers. Ideally, payments are processed by data transfer, thus reducing the time to cash for the service providers.

The External Distributors

For the travel agency, the external distributors deliver the actual service to the customer. The external distributor is the service provider of the transportation or tour (the

airline, the cruise company, the tour guides, the car rental agency, etc.). Although the agency makes all of the arrangements, the service provider is not part of the agency.

Services deal with many of the same issues that face manufacturers. The intent is to integrate the internal operations (arranging for the travel, billing the customer, paying the service suppliers, and tracking the services provided to the customer).

MAJOR ISSUES AFFECTING SUPPLY CHAIN MANAGEMENT

Information Technology

Information technology enablers for supply chain management include the Internet, the Web, EDI (electronic data interchange), intranets and extranets, bar code scanners, and point-of-sale demand information. We begin by looking at the use of the Internet and the Web as a way of doing business.

E-Commerce

E-commerce and e-business are defined as the use of the Internet and the Web to transact business. E-business refers to transactions and processes within an organization, such as a company's on-line inventory control system, that support supply chain management. E-commerce includes B2B (business-to-business) and B2C (business-to-consumer) transactions. Let's take a closer look B2B e-commerce.

▶ **E-commerce**
Using the Internet and Web to transact business.

Business-to-Business (B2B) E-Commerce

In **business-to-business e-commerce**, companies sell and buy products to and from other businesses. B2B represents the largest segment of e-commerce sales transactions. Prior to the Internet, B2B was relativeiy inefficient. It took time and resources for companies to search for products, to arrange for purchase and payment, to handle shipment, and finally to receive the items. Using the Internet allowed companies to automate at least parts of the procurement process. Significant dollars are saved by organizations due to effective electronic purchasing research and reduced transaction costs. Let's look at how B2B commerce has developed.

▶ **Business-to-business e-commerce**
Businesses selling to and buying from other businesses.

The Evolution of B2B Commerce

B2B commerce began in the 1970s with **automated order entry systems** that used telephone models to send digital orders to suppliers. One company, Baxter Healthcare Corporation, placed telephone modems in a customer's purchasing department to automate reordering supplies from Baxter's computerized inventory database. This technology changed in the 1980s to personal computers and in the 1990s to Internet workstations that access on-line catalogs. Automated order entry systems are seller-side solutions. They are owned by the supplier and only offer the supplier's product line. The primary benefits to the customers are reduced inventory replenishment costs and supplier-paid system costs.

▶ **Automated order entry system**
A method using telephone models to send digital orders to suppliers.

In the late 1970s, **electronic data interchange (EDI)** emerged. EDI is a form of computer-to-computer communication standardized for sharing business documents such as invoices, purchase orders, shipping bills, and product stocking numbers. Most

▶ **Electronic data interchange (EDI)**
A form of computer-to-computer communications that enables sharing business documents.

large firms have EDI systems, and most inventory groups have industry standards for defining the documents to be communicated. EDI systems are buyer-side solutions: they are designed to reduce the procurement costs for the buyer. EDI systems generally serve a specific industry.

▶ **Electronic storefronts**
On-line catalogs of products made available to the general public by a single supplier.

In the mid-1990s, **electronic storefronts** emerged. Electronic showplaces are on-line catalogs of products made available to the general public by a single supplier. These storefronts evolved from the automated order entry systems. They are far less expensive than their predecessors because (1) they use the Internet as the communication medium, and (2) the storefronts tend to carry products that serve a number of different industries.

▶ **Net marketplaces**
Suppliers and buyers conduct trade in a single Internet-based environment.

Net marketplaces emerged in the late 1990s. A net marketplace is designed to bring hundreds or thousands of suppliers (each with electronic catalogs) together with a significant number of purchasing firms in a single Internet-based environment to conduct trade. Covisint (www.covisint.com) is an example of a successful net marketplace. Covisint was started in 1999 by a consortium of the following auto manufacturers: General Motors, Ford Motor Company, DaimlerChrysler, Nissan, and Renault. Its purpose was to address escalating costs and gross inefficiencies within their industry. Covisint leveraged the power and potential of the Internet to solve industry-specific business problems in real time. Its goal was to deliver a secure marketplace, portal, and application-sharing platform for the global automotive industry. Currently, Covisint has more than 300,000 users that represent more than 45,000 organizations, and does business in 96 countries. Covisint streamlines and automates business processes, globally connecting business communities in the manufacturing, healthcare, aerospace, public sector, and financial services industries.

▶ **Electronic request for quote (eRFQs)**
An electronic request for a quote on goods and services.

A net marketplace can also facilitate on-line auctions. Two types of auctions are forward auctions (where suppliers auction excess inventory and receive the market price for their surplus goods) and reverse auctions (where buyers post **electronic requests for quotes (eRFQs)** for goods and services and suppliers bid for business on-line).

▶ **Virtual private network (VPN)**
A private Internet-based communications environment that is used by the company, its suppliers, and its customers for day-to-day activities.

A **virtual private network (VPN)** is a computer network in which some of the links between nodes are carried by open connections or virtual circuits on the Internet instead of by physical wires. An organization can have a VPN for use by its own employees as well as suppliers and customers. Through this network, buyers and suppliers can work together on product design and development, manage inventory replenishments, coordinate production schedules, and work as partners. Access to the VPN is typically password controlled. More than likely, your university has a VPN for your use.

The Benefits of B2B E-Commerce

The potential benefits from Internet-based B2B commerce include:

- Lower procurement administrative costs.
- Low-cost access to global suppliers.
- Lower inventory investment due to price transparency and quicker response times.
- Better product quality because of increased cooperation between buyers and sellers, especially during product design and development.

Business-to-Consumer (B2C) E-Commerce

In **business-to-consumer e-commerce**, on-line businesses try to reach individual consumers. Let's examine the different models that on-line businesses use to generate revenue. In the **advertising revenue model**, a Web site offers its users information on services and products, and provides an opportunity for providers to advertise. The company receives fees for the advertising. Yahoo.com derives its primary revenue from selling advertising such as banner ads.

In the **subscription revenue model**, a Web site that offers content and services charges a subscription fee for access to the site. One example is Consumer Reports Online (www.consumerreports.org), which provides access to its content only to subscribers at a rate of $3.95 per month. Companies using this model must offer content perceived to be of high value that is not readily available elsewhere on the Internet for free.

In the **transaction fee model**, a company receives a fee for executing a transaction. For example, Orbitz (www.orbitz.com) charges a small fee to the consumer when an airline reservation is made. Another example, E*Trade Financial Corporation, an on-line stockbroker (www.etrade.com), receives a transaction fee each time it executes a stock transaction.

In the **sales revenue model**, companies sell goods, information, or services directly to customers. Amazon.com, primarily a book and music seller, Travelocity.com, an airline and hotel reservations provider, and DoubleClick Inc. (www.doubleclick.net), a company that gathers information about on-line users and sells it to other companies, all use the sales revenue model.

In the **affiliate revenue model**, companies receive a referral fee for directing business to an "affiliate" or receive some percentage of the revenue resulting from a referred sale. For example, MyPoints.com receives money for connecting companies with potential customers by offering special deals. When members take advantage of the deal, they earn points that can later be redeemed for goods.

In addition to the Internet, companies use other technology to help manage supply chains. For example, **intranets** are networks internal to an organization. Intranets allow a company to network groups of internal computers together to form more effective information systems. Typically, members of the organization communicate internally on the intranet. Organizations can link intranet systems of the Internet to form **extranets**. The extranet can be expanded to include both a company's suppliers and customers. Typically, real-time inventory status is available on the extranet as well as production schedules. Extranets allow suppliers and customers to "see" within the organization. The primary difference between the Internet, intranets, and extranets is who has access to the system. The Internet is wide open, the intranet is open to members of an organization, and the extranet is open to members of the organization as well as to suppliers and customers.

▶ **Business-to-consumer e-commerce (B2C)**
On-line businesses sell to individual consumers.

▶ **Advertising revenue model**
Provides users with information on services and products and provides an opportunity for suppliers to advertise.

▶ **Subscription revenue model**
A Web site that charges a subscription fee for access to its contents and services.

▶ **Transaction fee model**
A company receives a fee for executing a transaction.

▶ **Sales revenue model**
A means of selling goods, information, or services directly to customers.

▶ **Affiliate revenue model**
Companies receive a referral fee for directing business to an affiliate.

▶ **Intranets**
Networks that are internal to an organization.

▶ **Extranets**
Intranets that are linked to the Internet so that suppliers and customers can be included in the system.

Consumer Expectations and Competition Resulting from E-Commerce

On-line retailing, or business-to-consumer e-commerce, has shifted the power from the suppliers to the consumers. This shift in power has occurred because the Internet greatly reduced search and transaction costs for the consumer. It was estimated as early as April 2001 that some 100 million people and over 80 percent of all individuals with Internet access had purchased something (either a product or a service) on-line. In

addition, millions more customers researched products on-line and subsequently bought those items off-line. The capability to quickly search, evaluate, compare, and purchase products gives the consumer considerable power. Examples of successful B2C businesses are Amazon.com, eBay, BMG Music Service, Barnes&Noble.com, Columbia House, Half.com, and JCPenney. E-tailers have penetrated significantly the following markets: computer hardware and software, books, travel, music and videos, collectibles and antiques, and event tickets.

Since customers have access to so many suppliers, it is important for suppliers to differentiate themselves by providing customers with excellent value. Dell Computer Corporation, Gateway, Inc., L.L.Bean, Inc., Lands' End, Inc., Amazon.com, UPS, and FedEx are good examples of companies that put a premium on values such as preferred customer service, short lead times, and/or quality guarantees. Dell differentiates itself with short lead times. The company does this by warehousing most of the components used to assemble its computers within 15 minutes of the assembly facility and building customized computers in an assemble-to-order strategy.

LINKS TO PRACTICE

Lands' End, Inc.
www.landsend.com

Courtesy My Virtual Model Inc.

Consider how Lands' End uses technology in its business. Lands' End went on-line in 1995. The company sold only $160 worth of gear the first month. Today, Lands' End is one of the nation's largest apparel retailers on-line. The company has a live chat room that allows customers to ask questions about merchandise. It also offers a "shopping with a friend" service that allows a customer, his or her friend or friends, and a customer service representative to be linked together. Lands' End's "virtual model" highlights how far technology has advanced. A few strokes on the keyboard and the shopper is able to produce an on-screen model with his or her body measurements. Even though this virtual model is not perfect, over 1 million shoppers have built their own models at the Lands' End site.

An additional issue here is how companies handle the return of unwanted merchandise and provide for product exchanges or refunds. The Boston Consulting Group (BCG) reported that the "absence of a good return mechanism" was the second-highest reason shoppers cited for not shopping on the Web. There are methods for handling returns. An on-line company often first requires authorization to return an item, then the customer must pack up the item, pay to ship it back to the company, insure the item, and then wait for a credit to be made. Once the item is returned, the original seller must unpack the item, inspect the item, check the paperwork, and try to resell the item. Typically, neither the buyer nor seller is happy with the process.

Another approach allows the customer to drop the returned items at collection stations (sometimes the physical stores of the company, for example, Staples, Inc., Sears, OfficeMax, Inc., etc.). The returned items can then be sold from the receiving store or picked up in bulk and returned to the distribution point. Another approach is to completely outsource returns. FedEx and UPS provide such services.

In addition to buying products on-line, consumers also buy on-line services. Finance, insurance, real estate services, business services, and health services are the largest on-line service industries. Business services include consulting, advertising and marketing, and information processing.

Service organizations are categorized either as those that do transaction brokering or those that provide a "hands-on" service. An example of transaction brokering is a company providing financial services that has stockbrokers acting as intermediaries between buyers and sellers of stock. An example of a "hands-on" service is a legal service that interacts directly with the consumer to create a legal document. In general, most service organizations are knowledge- and information-intense. To provide value to consumers, these service companies must process considerable information (legal services or medical services) and employ a highly educated and skilled workforce (lawyers and doctors).

Globalization

As globalization continues to increase, supply chains cover greater geographical distances, face greater uncertainty, and can end up being less efficient. Beginning in 2004, prices for steel, oil, copper, cement, and coal began rising at double-digit rates. These increases led buyers to look globally for lower-cost alternative suppliers. After purchasing items offshore, companies were challenged with moving the commodities over longer distances. This increase in volume resulted in a transportation capacity crunch and led to higher transportation rates. The lack of capacity slowed down supply chains, causing inventory levels to rise. The U.S. Commerce Department reported an increase in the level of inventory by November 2004 to 1.24. This means that it took approximately $1.24 of inventory to support every dollar of sales. In 2008, transportation rates went even higher due to the very high fuel costs. These higher costs have prompted companies to reexamine their offshore sourcing and to consider returning to onshore suppliers.

Ocean carriers have predicted that the volume of goods shipped from Asia to the United States will continue to have double-digit annual increases. Most of these inbound goods are shipped through U.S. West Coast ports. The higher trade volume has caused port congestion in California and Washington State. In an effort to ease port congestion, ocean carriers introduced larger ships for use on the transpacific routes. While it was hoped that these larger ships would add needed capacity and reduce operating costs, only a few U.S. ports are capable of handling the larger ships. The ships take longer to unload and reload, tying up the port for five to seven days rather than the normal two days. The longer port time has reduced terminal efficiency. Previously, importers were allowed more free time (the time cargo may occupy assigned space free of storage charges) for containers at U.S. port terminals. Container free time basically provided a cheap form of portable warehousing for importers. Because of the terminal inefficiency, container free time has been reduced and ports have increased storage capacity in an effort to turn equipment around faster.

Another issue is border security. Since September 11, 2001, the U.S. Bureau of Customs and Border Protection (CBP) has implemented new requirements. Essentially, these programs result in additional processing time. The CBP has also increased inspections at ports of suspicious cargo, creating additional port delays.

As supply chains expand globally, they share some common logistical characteristics. For example, with ocean shipping, goods tend to arrive at a warehouse in very large quantities. Because of bulk arrivals, greater break-bulk activity is required.

Break-bulk entails sorting the bulk shipments into smaller customer shipments. These global supply chains typically have higher inventory levels. Managing global supply chains will be challenging in the near future.

Government Regulation and E-Commerce

The issue of government regulation of the Internet is still unresolved. Although early Internet users claimed the Internet could not be controlled given its decentralized design and its ability to cross borders, it is clear that the Internet can be controlled. In China, Malaysia, and Singapore, access to the Internet is controlled from government-owned centralized routers. This allows these countries to block access to U.S. or European Web sites. Search engines operating in these countries self-censor their Asian content by using only government-approved news sources. In other countries, freedom of expression has limited restrictions on the Internet. In order for leading Internet company Google to access China's fast-growing market, it agreed to censor its search services. E-mail, chat room, and blogging services will also not be available because of concerns the government could demand users' personal information. Google indicated that it would notify users when access had been restricted on certain search terms.

Another issue of concern is taxation. The question is how, and if, remote sales should be taxed. Think of the advantage gained by e-tailers over local merchants when no taxes are charged to the consumer. In addition to sales taxes, the issue of customs and tariffs must be addressed. Taxation remains a very complicated issue for Internet sales.

Copyright infringement is also an issue. The U.S. copyright law protects original forms of expression such as writing (books, periodicals), art, drawings, photographs, music, motion pictures, performances, and computer programs from being copied by others for a minimum of 50 years. One exception to the U.S. copyright law is the doctrine of fair use. This doctrine allows teachers and writers to use materials without permission under certain circumstances. In response to copyright issues, the U.S. government enacted the Digital Millennium Copyright Act (DMCA) of 1998. The DMCA declares it illegal to make, distribute, or use devices that circumvent technology-based protections of copyrighted materials and attaches stiff fines and prison sentences for violations.

Another issue concerns public safety and welfare. In the United States, e-commerce issues of safety and welfare center around the protection of children, strong antipornography sentiments, strong antigambling positions, and protection of public health by restricting sales of drugs and cigarettes. It is clear that many issues concerning government regulation of the Internet are yet to be determined.

Green Supply Chain Management

▶ **Green supply chain management**
Focuses on the role of the supply chain with regard to its impact on the environment.

Recently, **green supply chain management** has focused on the role of the supply chain with regard to its impact on the present natural environment as well as to the generation of any future environmental change. The intent is to be able to meet our present needs without compromising the ability of future generations to meet their own needs. So, how do we green supply chains?

A number of organizations have introduced "greening" requirements for both their suppliers and distributors. These requirements can be purchasing clauses,

Michael L. Abramson/Time Life Pictures/Getty Images, Inc.

specified supply chain goals (carbon emission footprint reduction, reduced energy consumption, reduced inventory levels, reduced transportation costs, etc.), practices (the use of sustainable farming, agreeing not to use specified materials, etc.), and use or nonuse of specific technologies. Some companies develop a corporate sustainability plan, which is then translated into a code of conduct, This code can be shared with both suppliers and distributors. Members of the supply chain are monitored for compliance. If violations of the code are found, corrective action is taken with the intent of building a better supply chain capability. In short, the organization is telling the members of its supply chain: "This is what you must do to be part of our supply chain. If you don't, we fix it. If it doesn't get fixed, we find a new member for our supply chain." The debate centers around how many organizations have that much leverage with members of their supply chain. Clearly, an organization such as Wal-Mart has considerable leverage. In fact, it uses a packaging scorecard to evaluate packaging compliance by members of its supply chain.

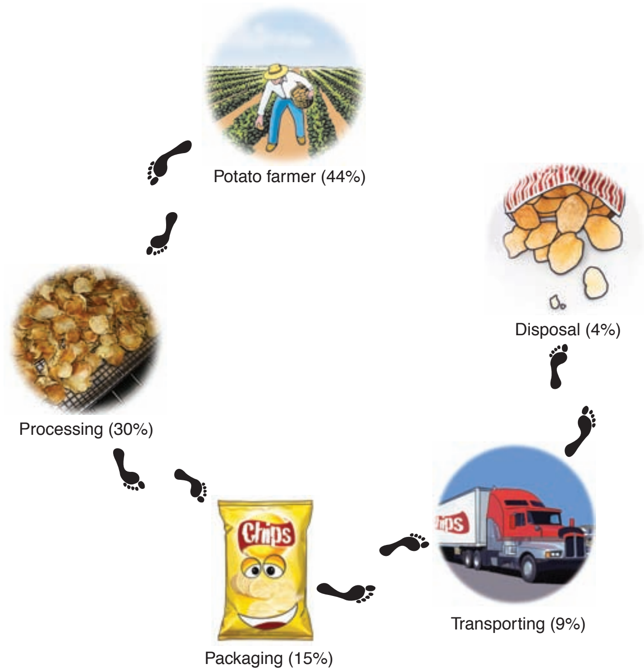
For supply chains doing business globally, it is important that they understand the packaging restrictions. For example, within the European Union cardboard boxes must be removed from consumption sites and recycled. As a result, U.S. automobile parts producers ship products in reusable containers rather than disposable contains. Reusable packaging products are used to move, store, and distribute products within a single operation or an entire supply chain. Plastic reusable packaging, a form of reusable packaging, can be used to package anything from raw materials to finished goods. It can be used within reverse logistics to return empty containers or pallets for reuse or replenishment. Products include handheld containers, pallets, bulk containers, protective interiors, and custom-designed and engineered packaging.

Companies doing business globally must also focus on the final disposition of products and packaging. The Herman Miller Company uses a design for the environment approach in new product design. To eliminate confusion as to what is a sustainable product, Herman Miller uses the McDonough Braungart Design Chemistry certification process, which is a "cradle-to-cradle" protocol for designing products in such a way that they are better for the environment. For Herman Miller, the issues centered on chemicals used and ease of disassembly of recyclable parts. It is clear that for global supply chains it will be important to be green, not only in terms of the environment but also in terms of eliminating waste and allowing the supply chain to be financially solvent.

Other organizations perform supply chain carbon footprint analysis. Consider the following simple supply chain example shown in Figure 4-5. When looking at the supply chain for potato chips, the chain begins with the farmer growing the potatoes, moves to the manufacturing of the chips, then their packaging, the transporting of the chips to the customer, and finally the disposal of the empty packaging. If you mapped out the carbon footprint for this supply chain, you would find that 44 percent of the carbon footprint occured at the farm, 30 percent in the manufacturing of

FIGURE 4-5

Carbon footprint of potato chip supply chain



the chips, 15 percent in the packaging process, 9 percent in transporting the chips to market, and only 2 percent in the disposal process. In this supply chain, it turns out that the farmer was overweighting the potatoes with water, since the manufacturer bought the potatoes based on weight. Because of how the potatoes were bought, they had too much water in them; this slowed down the manufacturing process, which needed to boil out excess water before processing the chips. When the manufacturer changed how potatoes were bought—based now on volume rather than on weight—the manufacturer required only half as much time to process the chips. This saved considerable energy and reduced the carbon footprint. Unfortunately, attention is often fixed on the disposal process, which can be a very small contributor to the overall carbon footprint. The gain in this example lies not only in reducing the footprint, but also in becoming a more efficient and effective supply chain by eliminating a waste-causing activity.

Infrastructure Issues

Global supply chains with members in developing countries can face substantial infrastructure issues (such as inadequate transportation networks, limited telecommunication capabilities, uncertain power continuity, low worker skill, poor supply availability and quality, etc.). Each of these issues increases uncertainty in supply and demand for the supply chain, which results in higher costs and poorer service.

Inadequate transportation networks increase distribution lead times. Roads may be inadequate to transport heavy loads (necessitating the creation of smaller loads), rail travel may not be available or very limited in terms of frequency (once or twice a week), air service may be limited in frequency (one or two flights per day or less), and ocean shipping may be limited by the capabilities of the port. It is not unusual for an item to change hands four to eight times before reaching the final customer.

Poor telephone service can restrict the timely availability of supply and demand information. Because of this, a more extensive information system to keep track of items is often required. An unstable power supply can significantly affect the output of a supplier, both in terms of when the product can be produced and the effect on product quality caused by unstable power.

A lack of specific worker skills can limit the technology a firm uses. For example, numerically controlled (NC) machines use more easily trained machine setters and programmers rather than more highly skilled machinists. The increased use of NC machines in South America is a result of an inadequate number of skilled machinists.

A lack of available local materials and competent suppliers can force a firm to redesign its process, or even its product, to minimize or eliminate the use of scarce materials. Imported raw materials may be difficult to obtain due to import restrictions. In some cases, no local suppliers are available. A case in point is McDonald's. When McDonald's started operations in Russia, it had considerable problems developing high-quality Russian suppliers. McDonald's used a vertically integrated strategy, developing its own plant and distribution facility for processing meat patties, producing french fries, preparing dairy products, and baking buns and apple pies. Initially, McDonald's even grew its own potatoes.

Product Proliferation

Global competition forces firms to supply highly customized products and services to multiple national markets. Usually, a firm manufactures a basic product that is adaptable to many markets. The basic product contains most of the features and components of the finished product along with some market-specific add-on components. For example, computer products have country-specific power supplies to accommodate local voltage, frequency, and plug types. In addition, keyboards and manuals must match the local language. Such minor variations create a large number of unique finished-product configurations to be managed. Product proliferation further complicates accurate demand forecasting.

Before You Go On

You need to understand the structure of a supply chain, the bullwhip effect, and the issues affecting supply chains. A supply chain structure has external suppliers, internal functions of the firm, and external distributors. Information technology enables supply chain management. E-commerce provides an effective means for communications between an organization and its suppliers and customers. Demand data provided through point-of-sale data (POS) helps counteract the bullwhip effect and reduces distorted demand information throughout the supply chain. Service organizations also have supply chains, all of which face many major issues. Issues such as information technology, the Internet, demand uncertainty, government regulations, the need for greener supply chains, inadequate infrastructures, and product proliferation can affect all supply chains.

THE ROLE OF PURCHASING

A company's purchasing department plays an important role in supply chain management decisions. Purchasing is typically responsible for selecting suppliers, negotiating and administering long-term contracts, monitoring supplier performance, placing orders to suppliers, developing a responsive supplier base, and maintaining good

supplier relations. Since material costs may represent at least 50–60 percent of the cost of goods sold, purchasing significantly affects profitability. Moreover, changes in product cost structure, with materials comprising the bulk of the cost of goods sold, have elevated the role of purchasing in many organizations.

Let's look at how purchasing has been done traditionally and also look at e-purchasing.

The Traditional Purchasing Process

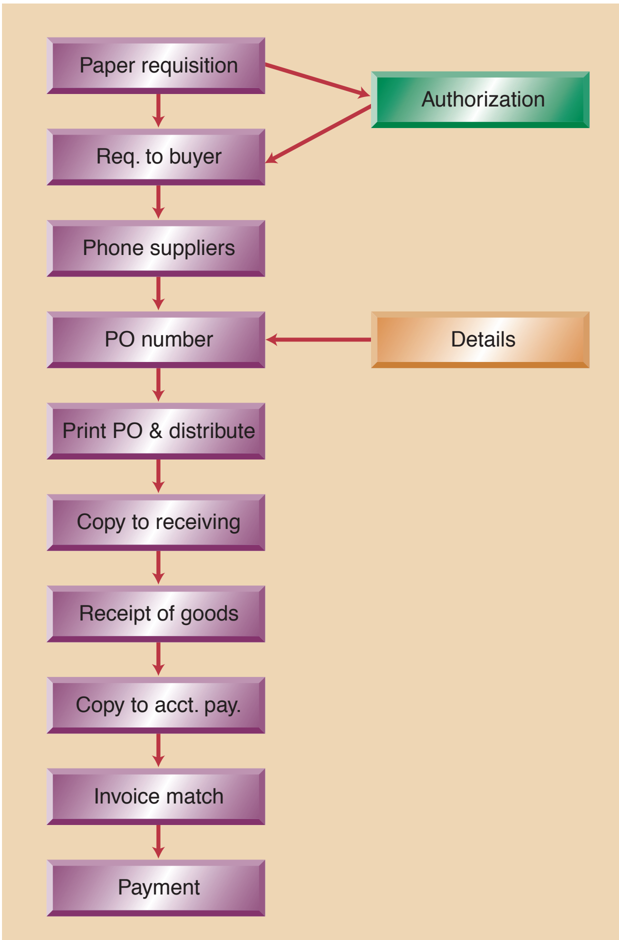
▶ **Requisition request** Request indicating the need for an item.

▶ **Price and availability** The current price of the item and whether the quantity is available when needed.

Before companies introduced e-purchasing, purchases were made following a flow similar to that shown in Figure 4-6. Typically, the process began when a requisition request was created, often by a production planner, an inventory planner, or an administrative staff member. A **requisition request** is simply a form used to inform purchasing that an item or a material needs to be purchased. Before any action is taken on the request, it may need to be authorized, by either a supervisor or a manager. The level of authority needed is often based on the dollar amount of the requisition. The higher the amount, the higher the level of authority needed to okay the purchase. After the requisition has been authorized, it goes to purchasing and is given to the specific buyer responsible for making that type of purchase. The buyer contacts potential suppliers of the item to determine **price and availability** for the item being requested. After analyzing the information from the different suppliers, the buyer de-

FIGURE 4-6

Traditional purchasing process



cides where to place the order. At this point it is time to release a **purchase order** confirming all the details of the purchase. A purchase order number is assigned to facilitate tracking the order through the system.

▶ Purchase order
A legal document committing the company to buy the goods and providing details of the purchase.

Then printed copies of the purchase order are distributed typically to the supplier, the initial requestor, accounts payable, the receiving dock, and the purchasing department. The purchase order is the company's commitment to the supplier to buy the item. A copy goes to the initial requestor to let the person know the item has been ordered and to provide delivery date information. Accounts payable needs a copy to reconcile the actual bill received with the negotiated terms of the purchase order with regard to quantity and price. The receiving dock gets a copy so that it knows the item has been ordered and it is okay to accept delivery of the package. The purchasing department typically keeps a copy for its file on that specific supplier. This allows the department to rate the performance of the supplier in terms of on-time delivery performance, quality and quantity, and billing accuracy.

When the item arrives at the receiving dock, the copy of the purchase order is checked to confirm that the item was ordered by the company and should be accepted. The goods then might move to **incoming inspection** for quality verification. From incoming inspection they are taken to the storeroom and put into inventory until they are needed.

▶ Incoming inspection
Verifies the quality of incoming goods.

When the company receives the invoice for the goods, before authorizing payment of the invoice the accounts payable department verifies that the goods have been received and that the cost per unit matches the purchase order terms.

In the past, this process tended to be slow, was prone to errors, and clearly was in need of a better way. Many companies now do e-purchasing to reduce transaction costs and provide an effective purchasing system.

The E-purchasing Process

E-purchasing is defined as the use of information and communications technology through electronic means to enhance external and internal purchasing and supply management processes. It is not just automating the purchasing function, but requires that an organization have a well-defined purchasing and supply management strategy. It requires that an appropriate **sourcing strategy** be developed.

▶ Sourcing strategy
A plan indicating suppliers to be used when making purchases.

Let's begin by looking at the e-purchasing process shown in Figure 4-7. From first glance, it is evident that the process has been streamlined and that some activities have been eliminated. The e-purchasing process begins with the initial requestor

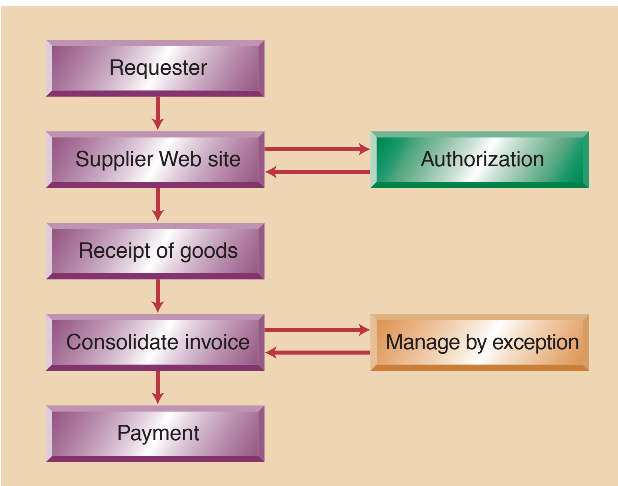


FIGURE 4-7

The e-purchasing process

TABLE 4-1

Key Features of E-Purchasing Systems

- Web-based purchase order approval
- Automatic routing of orders requiring additional authorization to appropriate recipient
- Automatic routing of completed purchase order copies to additional recipients
- Notification of receipt to appropriate recipients
- Secure e-mail sending, using standard electronic signature
- Electronic archiving to facilitate supplier evaluation and analysis of purchasing trends

going to the approved supplier's Web site or the appropriate net marketplace to place the order. The company may have preauthorized spending limits set for each of its individual requestors. Any order exceeding that limit would be routed to the necessary approving authority before being processed further. Once the order is in process, all the members of the organization who need to know about the transaction learn in real time all the details associated with the order. This is the same information that they previously learned from their copy of the purchase order. When the goods are received, this fact is inputted into the system so that receipt information is provided to the interested parties. Instead of preparing an invoice for each individual shipment, the supplier consolidates invoices over a period of time and sends a single invoice to the company. This reduces supplier transaction costs. Accounts payable verifies the information on the consolidated invoice and authorizes payment. One check or funds transfer is made for all the orders placed with the supplier rather than a separate check or transfer for each individual order. This reduces the accounting transaction costs for the purchasing company. Key features of typical e-purchasing systems are shown in Table 4-1.

A summary of the expected benefits to the buyers from e-purchasing is shown in Table 4-2. Basic benefits are cost savings, fewer human errors, and a more efficient purchasing process.

To successfully use e-purchasing, there must also be benefits for the suppliers. Table 4-3 shows some of the expected benefits for suppliers.

TABLE 4-2

Benefits to the Buyers from E-Purchasing Systems

- Reduced purchase order processing costs
- Reduced purchase order cycle times
- Less data entry, thus reduced order processing time
- Reduced paperwork
- More efficient distribution of information throughout the system
- Reduced buyers' research time with electronic catalogs and net marketplaces
- Fewer order processing errors leading to incorrect shipments
- Consolidated data to facilitate analysis of purchasing patterns and supplier performance
- Share performance measurement data, which encourages improved supplier performance
- Reduced inventory because of better supplier performance

TABLE 4-3

Benefits for Suppliers Engaged in an E-Purchasing Environment

- Time savings since orders do not need to be reentered
- Fewer input errors
- Reduced transaction costs and reduced purchase order cycle times
- Less inventory as a result of more efficient communications with customers
- Better forecasting information from customers
- Better supplier performance since supplier measurement information is shared
- Faster payment
- Improved information flow

Many organizations engaged in e-purchasing establish a Web site that potential suppliers can visit to determine what current opportunities are available. Typically, suppliers must register to access the site, and subsequent entry is controlled by a password. Shown in Table 4-4 is an example of a Web site used by a county government to interact with its suppliers. The Web site informs potential suppliers on how to register for the site and how to certify itself as a supplier, and it shows the current opportunities

TABLE 4-4

Example of a Web Site Used by a Government Organization

Northeast County E-Purchasing

E-Purchasing

Welcome to Northeast County's E-Purchasing Web site!

The Purchasing Division is responsible for the management and coordination of the acquisition of goods and services, including requisition processing, commodity code tracking, and bid specifications.

HOW TO DO BUSINESS WITH NORTHEAST COUNTY

Step 1 REGISTER WITH PURCHASING

Persons or concerns desiring to be registered on the County's Bidder List for goods and/or services must complete and submit a completed Vendor Registration Form.

Registration can be completed online or **in person**.

Step 2 CERTIFY WITH HUMAN RELATIONS

FEP compliance is required for all contracts greater than $50,000 (supply/service) and $100,000 (construction),

Northeast County Certification Categories:

- Fair Employment Practice (FEP)
- Northeast County Based Enterprise (CBE)
- Small Business Enterprise (SBE)
- Targeted Growth Community Enterprise (TGCE)
- Expanding Business Enterprise (EBE)
- MBE/WBE (Declaration)
- Disadvantaged Business Enterprise (DBE)

Step 3 QUOTES OPPORTUNITIES

Quotes are published daily on this Web site.

available for which quotes can be submitted. Access to the Web site is limited by a password. Although the example shows a government organization's Web site, similar Web sites are used by manutacturing and service organizations.

Regardless of whether an organization engages in traditional purchasing, e-purchasing, or a combination of both, an organization must decide which sources are used. The issues of sourcing are discussed next.

SOURCING ISSUES

MKT

Which products or services are provided in-house by the manufacturer, and which are provided to the manufacturer by other members of the supply chain? **Vertical integration** is a measure of how much of the supply chain is owned or operated by the manufacturer. Products or services provided by the manufacturer are **insourced**. Products or services not provided by the manufacturer are **outsourced**. Outsourcing means that the manufacturer pays suppliers or third-party companies for their products or services, a practice that is on the rise. A recent survey reported that 35 percent of more than 1000 large companies have increased their outsourcing. Another survey of large companies reported that 86 percent outsourced at least some materials or services. The activity most frequently outsourced was manufacturing.

▶ **Vertical integration**
A measure of how much of the supply chain is actually owned or operated by the manufacturing company.

▶ **Insource**
Processes or activities that are completed in-house.

▶ **Outsource**
Processes or activities that are completed by suppliers.

▶ **Backward integration**
Owning or controlling sources of raw materials and components.

▶ **Forward integration**
Owning or controlling the channels of distribution.

Backward integration is a company's acquisition or control of sources of raw materials and component parts: the company acquires, controls, or owns the sources that were previously external suppliers in the supply chain. **Forward integration** is a company's acquisition or control of its channels of distribution—what used to be the external distributors in the supply chain.

A company bases its level of vertical integration on its objectives. The greater the vertical integration, the lower is the level of outsourcing. Conversely, the higher the level of outsourcing, the lower is the level of vertical integration. Some factors favor vertical integration. For example, companies needing a high volume of a product or service can sometimes achieve economies of scale by providing the product or service in-house. Companies with special skills may find that it is cheaper to provide certain products or services in-house. Other factors encourage outsourcing. For example, companies with low volumes generally find it cheaper to outsource a product or service rather than provide it in-house. Sometimes a company can get a better-quality product or service from a supplier than it can provide itself.

Now let's look at the financial calculations behind insourcing and outsourcing decisions.

Insourcing versus Outsourcing Decisions

It may be easy to calculate the costs of insourcing versus outsourcing and make the right financial decision. But such decisions involve more than financial calculations. Is a particular product or service critical to your company's success? Is the product or service one of your company's core competencies? Is it something your company must do to survive? If the answer is yes to any of these questions, your company will provide the product or service in-house. If the product or service is not one of its core competencies, the company needs to decide whether it should make or buy the product or service. Other considerations are, for example, whether the products or services provided in-house are identical to those outsourced. Is product quality in-house comparable to product quality in the marketplace? Is product functionality comparable, or does one product have an advantage in terms of quality or functionality? Finally, does

the company have the capital needed for any up-front costs to provide the product or service in-house?

Now let's look at how a company might make the financial calculations. To make a financial calculation, we look at the total costs involved in either producing the entire quantity in-house or buying the entire quantity from a supplier. The total cost of buying the item is any fixed annual cost associated with buying the product plus a variable cost for each item bought during the year, or

$$TC_{\text{Buy}} = FC_{\text{Buy}} + (VC_{\text{Buy}} \times Q)$$

where TC_{Buy} = total annual costs of buying the item from a supplier
FC_{Buy} = fixed annual costs associated with buying the item from the supplier
VC_{Buy} = variable costs per unit associated with buying the item from the supplier
Q = quantity of units bought

Similarly, we calculate the total cost of making the item in-house as

$$TC_{\text{Make}} = FC_{\text{Make}} + (VC_{\text{Make}} \times Q)$$

where TC_{Make} = total annual costs of making the item in-house
FC_{Make} = fixed annual costs associated with making the item in-house
VC_{Make} = variable costs per unit associated with making the item in-house
Q = quantity of units made in-house

The first step in solving the make-or-buy decision is to determine at what quantity the total costs of the two alternatives are equal. To do this, we set the total annual cost of buying equal to the total annual cost of making:

$$FC_{\text{Buy}} + (VC_{\text{Buy}} \times Q) = FC_{\text{Make}} + (VC_{\text{Make}} \times Q)$$

Solving this tells us the *indifference point*—that is, how many units we must buy or produce when the total costs are equal. If we need this exact amount, we would be indifferent to whether we bought the item or produced it in-house. If we need less than this quantity, we choose the alternative with the lower fixed cost and the higher variable cost. If we need more than this quantity, we choose the alternative with the lower variable costs.

Let's look at a numerical example. Remember that when the quantity needed exceeds the indifference point, use the alternative with the lower variable cost. If the usage quantity is below the indifference point, then choose the alternative with the lower fixed cost.

EXAMPLE 4.1

MS Bagel Shop: A Make-or-Buy Decision

Two recent college graduates, Mary and Sue, have decided to open a bagel shop. Their first decision is whether they should make the bagels on-site or buy the bagels from a local bakery. They do some checking and learn the following:

- If they buy from the local bakery, they will need new airtight containers in which to store the bagels delivered from the bakery. The fixed cost for buying and maintaining these containers is \$1000 annually.
- The bakery has agreed to sell the bagels to Mary and Sue for \$0.40 each.
- If they make the bagels in-house, they will need a small kitchen with a fixed cost of \$15,000 annually and a variable cost per bagel of \$0.15.
- They believe they will sell 60,000 bagels in the first year of operation.

(a) Should Mary and Sue make or buy the bagels?

(b) If Mary and Sue are uncertain as to the demand for bagels next year, what is the indifference point between making or buying the bagels?

- **Before You Begin:** To make their decision when demand is known, Mary and Sue need to calculate the total cost of making or buying 60,000 bagels. Determine the relevant data for these calculations. To find the total annual cost of buying 60,000 bagels, you need both the annual fixed costs ($1000) and the variable cost per bagel ($0.40). To calculate the total annual cost of making the 60,000 bagels, you need the annual fixed costs ($15,000) and the variable cost per bagel ($0.15).

- **Solution:**

(a) The total cost for buying 60,000 bagels is $25,000. That is $1000 in annual fixed cost plus 60,000 bagels multiplied by the $0.04 unit variable cost. The total cost for making 60,000 bagels is $24,000. That is $15,000 in annual fixed costs plus the 60,000 bagels multiplied by the $0.15 unit variable cost.

(b) If Mary and Sue don't know the demand for bagels, they can find the indifference point by setting the total annual costs of each option equal to the other, as shown below. Although in this problem we are comparing the options of making or buying, we could just as easily compare two different suppliers or two different internal processes.

Set the total annual costs equal to each other using the formula.

$$FC_{\text{Buy}} + (VC_{\text{Buy}} \times Q) = FC_{\text{Make}} + (VC_{\text{Make}} \times Q)$$

or

$$\$1000 + (\$0.40 \times Q) = \$15{,}000 + (\$0.15 \times Q)$$

Solving for Q, we have $(\$0.25Q) = \$14{,}000$, or $Q = 56{,}000$ bagels. Since the costs are equal at 56,000 bagels and Mary and Sue expect to use 60,000 bagels, they should make the bagels in-house rather than buy them from the local bakery. By making the bagels, the cost for each additional bagel above 56,000 is $0.15 instead of the $0.40 they would pay the local bakery for each bagel.

Outsourcing requires decisions about which supplier to contract with for products or services. These decisions in turn depend on the criticality and frequency of the product or service, and they determine the relationship the company forms with the supplier. For example, if the purchase is one-time only, the company does not need to develop a relationship with the supplier. However, if the company wants a reliable supplier for a critical product or service, it needs to develop a long-term relationship with the supplier.

Developing Supplier Relationships

A strong supplier base is essential to the success of many organizations. Choosing a supplier is like choosing where to shop for something you want to buy. The first thing you decide is which merchants have the product or service you want. Adequate quality for the product or service is usually a prerequisite for even considering a merchant. What else is important to you when choosing a merchant? Availability, perhaps size and color for clothing, freshness and appearance for produce, and physical proximity so you can see the product or try it on. Quick response time, such as overnight shipping or rapid alterations; price, of course; ease of doing business; reputation; and warranty or service agreements are all considerations.

What is important to you as an individual when choosing a merchant is also important for your company when choosing a supplier. In general, we want merchants or suppliers who give us good value. Several studies report that the top three criteria for selecting suppliers are price, quality, and on-time delivery. Even more important,

however, is that the choice of suppliers be consistent with a company's mission. For example, if your company is competing on the basis of quick response time, your suppliers must offer minimal lead times and be able to respond quickly.

How Many Suppliers?

Once your company has chosen its suppliers, the next question is: Should you give a single supplier all your business for a particular product or service? Or should you use multiple suppliers? Table 4-5 lists arguments in favor of a single supplier and multiple suppliers.

For some operations, like make-to-order products, it is easier to deal with a single supplier. This is especially true for scheduling deliveries, resolving problems, minimizing the cost of dies or tools, developing computer links, and so forth. In addition, using a single supplier can improve the quality of your finished product by ensuring the consistency of the input materials.

On the other hand, multiple suppliers reduce the risk of a disrupted supply—that is, if one supplier suffers a disaster, other suppliers can pick up the slack. Further, multiple suppliers can more easily support changing quantity requirements. For example, if you need a larger quantity than a single supplier can supply, the order can be split

TABLE 4-5

Arguments in Favor of One Supplier and of Multiple Suppliers

Pros of One Supplier	Pros of Multiple Suppliers
• The supplier may be the exclusive owner of essential patents and/or processes and thus be the only possible source. • By using one supplier, quantity discounts may be achieved. • The supplier will be more responsive if it has all of your business for the item. • Contractual agreements may prohibit the splitting of an order. • The supplier is so outstanding that no other supplier is a serious contender. • Single sourcing is a prerequisite for partnering. • The order is too small to split between suppliers. • When the purchase involves a die, tool, mold, or expensive setup, the cost of duplicating may be prohibitive. • Deliveries can be scheduled more easily. • Supports just-in-time manufacturing and EDI. • Allows for better supplier relations. • The just-in-time philosophy can be better utilized.	• Competition among suppliers may provide better service and price. • Probability of assured supply is better. Multiple suppliers spreads the risks. • Eliminates a supplier's dependence on the purchaser. • Provides a greater flexibility of volume. • No single supplier may have sufficient capacity. • Allows for testing of new suppliers without jeopardizing the flow of materials. • Government regulations may require multiple sources.

among multiple suppliers. This is referred to as flexibility of volume. Finally, government regulations may require the use of multiple suppliers for some projects.

The answer to how many suppliers depends on your supply chain structure. If your company wants to integrate its supply chain, then partnering or using a single supplier makes sense. For example, the trend in industry is toward a smaller supply base. A benchmarking study of 24 industries done by the Center for Advanced Purchasing Studies in 1994 reported a 6.5 percent average decrease in the number of active suppliers.

Developing Partnerships

▶ **Partnering**
A process of developing a long-term relationship with a supplier based on mutual trust, shared vision, shared information, and shared risks.

One compelling argument in support of using single suppliers is that it is often a prerequisite for developing a partnering relationship. **Partnering** with a supplier requires a commitment from both the company and the supplier. The goal is to establish an ongoing relationship in which both parties benefit from the arrangement—what is called a “win-win situation.”

The two kinds of partnerships are *basic* and *expanded*. A basic partnership is built on mutual respect, honesty, trust, open and frequent communications, and a shared understanding of each partner’s role in helping the supply chain achieve its objectives. Expanded partnerships are reserved for a few key suppliers. These are long-term relationships built on mutual strategic goals. Expanded partners must be committed to helping each other succeed. They must place a high priority on maintaining the relationship and on sharing information, risks, opportunities, and technologies.

LINKS TO PRACTICE

The Timken Company
www.timken.com

Courtesy Timken

The Timken Company produces high-quality, antifriction, tapered roller bearings and specialty alloy steels for global consumption. In 1987, Timken started a coordinated sourcing strategy aimed at improving the value of purchased products and reducing the supplier base. A cross-functional team at Timken initiated the process.

At a supplier conference, Timken executives explained to prospective suppliers the company’s concept of total value. Timken defines total value as quality, delivery, price, and responsiveness. Timken chose Wayne Steel Company, a steel service center, as its provider of strip steel. Wayne Steel has cutting-edge equipment and is known for its response to customers’ quality and service requirements. In addition, Wayne is a leader in close-tolerance, just-in-time programs. Because of this, Wayne can ship small quantities quickly to its customers—a major competitive advantage. Timken and Wayne struggled for three years to establish the partnership. This partnership enabled Timken to save $1 million because of a fixed-price clause during the first year of the contract and another $350,000 annually through reduction in freight and slitting costs. Wayne was able to reduce Timken’s lead time from three months to five days for cut-to-length flats and 48 hours for coils. Wayne delivered exact requirements (no minimum quantity requirements) to Timken. This eliminated the need for 7500 square feet of warehouse space. Inventory turns went from four to forty and inventory investment was reduced by $1.5 million. Wayne’s use of better material improved the yield rate at Timken by 4 percent.

For Wayne Steel, the benefits of the partnership were also obvious. With long-term commitments, Wayne was able to invest in the equipment and systems needed to differentiate itself from other steel service centers. Long-term relationships also support Wayne Steel's business philosophy. Wayne has a no-layoff policy because achieving its corporate objectives requires loyal and committed personnel. Long-term relationships also ensure a continuous level of business. This stability allows Wayne to invest in its workforce. The Timken–Wayne partnership illustrates the need for both partners to benefit if the partnership is to survive.

A company evaluating potential partners looks at the following aspects of the potential partner's business:

- History, sales volume, product lines, market share, number of employees, major customers, and major suppliers.
- Current management team in terms of past performance, stability, and strategic vision.
- Labor force in terms of skill, experience, commitment to quality, and relations with the supplier.
- Internal cost structure, process and technology capabilities, financial stability, information system compatibility, supplier sourcing strategies, and long-term relationship potential.

The company reduces the selection pool to a few potential partners, identifies a single partner, and commits to the partnership. At this point, both parties agree on how to measure the performance of the partnership. The partners set time frames for the frequency and methods of performance assessment and decide how problems will be resolved. When they reach agreement on these issues, the partners develop supply chain operating procedures and put the partnership into motion. Table 4-6 shows possible benefits from partnering.

Critical Factors in Successful Partnering

Impact, intimacy, and vision are critical factors in successful partnering. Impact means attaining levels of productivity and competitiveness that are not possible through normal supplier relationships. Intimacy means the working relationship between partners. Vision means the mission or objectives of the partnership. Let's look at each of these factors.

TABLE 4-6

Possible Benefits from Partnering

Manufacturer's Benefits	Supplier's Benefits
• Reduce costs	• Increase sales volume
• Reduce duplication of effort	• Increase customer loyalty
• Improve quality	• Reduce costs
• Reduce lead time	• Improve demand data
• Implement cost reduction program	• Improve profitability
• Involve suppliers earlier	• Reduce inventory
• Reduce time to market	
• Reduce inventory	

Impact comes through mutual change. The supplier and the customer must be willing to make changes. Studies suggest that the three sources of impact are reduction of duplication and waste, leveraging core competence, and creating new opportunities.

Duplication can involve any activity done by both the supplier and the customer. For example, suppliers count items before shipping, and customers count the same items after receipt. What value is added by having both parties count the same items?

Waste reduction means eliminating any activity that does not add value. For example, moving items into and out of storage adds no value. It makes sense to have items delivered to and stored where they are used.

LINKS TO PRACTICE

Sweetheart Cup Company
www.sweetheart.com

Georgia-Pacific Corporation
www.gp.com

Michael Newman/PhotoEdit

Duplication can also be eliminated in paperwork and administration. Sweetheart, a manufacturer of paper drinking cups, faced price-cutting demands from a major customer. Sweetheart was told prices needed to be reduced 10 percent or the customer would use a different supplier. To meet this challenge, Sweetheart partnered with paperboard producer Georgia-Pacific. A shared electronic data interface reduced paperwork and administration and cut expensive inventory. Joint planning optimized production plans, giving Sweetheart a more consistent product from Georgia-Pacific at a better price. Sweetheart can satisfy its high-volume customers, and Georgia-Pacific benefits through more business.

Leveraging core competence is about sharing knowledge. Different companies have different strengths or competencies. Instead of making the supplier or the customer reinvent the wheel, all partners can benefit from shared expertise. Following is an example.

Hillenbrand Industries, a manufacturer of hospital room equipment products, has six geographically dispersed manufacturing facilities. The company uses its own 400-truck fleet and both domestic and international carriers. Hillenbrand decided to partner with UPS to improve the cost, quality, and responsiveness of Hillenbrand's overall logistics. For UPS, fleet management is a core competence; for Hillenbrand, fleet management is an expensive, noncore requirement. Hillenbrand does not want to incur the expense of building a world-class core competence in fleet management. By partnering with UPS, Hillenbrand can leverage and benefit from its partner's expertise. Hillenbrand was able to create $1.5 million in cost improvements during the first year of the partnership. UPS revenues with Hillenbrand have grown by almost $2 million. Both the supplier and the customer have benefited.

Creating new opportunities means partners working together to produce something that neither could have achieved alone. Let's look at an example involving a tier one supplier to an automobile manufacturer.

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This supplier used to make daily truckload deliveries of a major subassembly to the auto assembly plant approximately 1200 miles away. Every day, four trucks left the supplier filled with subassemblies, and every day four of the supplier's empty trucks left the auto assembly plant. The supplier was wasting significant transport capacity, with empty trucks returning to its facility. To remedy the problem, the supplier worked with the automobile manufacturer to develop a new truck trailer that carried subassemblies to the automaker and also hauled new autos back to a major metropolitan area. Thus, the auto manufacturer could send new cars to market and eliminate

wasted transport capacity. Because the supplier transported the cars to market in an enclosed truck, protected from weather and road hazards, the cars arrived customer-ready. By using the empty trucks to haul the new autos to this market, the supplier eliminated the wasted transport capacity, provided a valuable service to the auto manufacturer, and generated cost savings for both partners. The partnership created a win-win situation that neither could have created alone.

Intimacy comes from the working relationship between partners. Because partners share confidential information, trust between them is critical. Intimacy means eliminating surprises: sharing daily information with partners prevents surprises. For example, a tier one supplier to the automotive industry needs to know how many autos are produced daily, any planned changes in production rates, and the current number of days of finished goods inventory. This information shows the supplier near-term demand and facilitates better customer service to the auto producer.

Intimacy is a result of sharing information. This information includes sales data collected at the point of sale; order change notices such as additional orders or cancellations; global inventory management, both quantity and location; and global sourcing opportunities so that supply chain members can improve purchase leveraging and component standardization.

The benefits of information sharing can be significant. When Osram GmbH bought GTE's Sylvania lighting division, it initiated a supply chain integration program. Within six months, fill rates were at 95 percent and climbing; individual stock keeping unit (SKU) forecast accuracy had improved by 16 percent; obsolete inventory was down 10 percent; and the company had saved more than $300,000 on transportation costs.

Vision is the mission or objective of the partnership. The partners must articulate and share their vision. This shared vision provides the structure for the partnership and the role each partner plays in achieving success for the supply chain.

Successful partnering needs a substantial commitment by both partners. Many companies try to reduce the number of their suppliers and develop a smaller, highly focused supplier base. The emphasis is on finding viable suppliers and developing long-term partner relationships. Table 4-7 summarizes the different aspects of partner relationships.

Monika Graff/The Image Works

Supermarkets use bar code scanners for obtaining point-of-sale information.

TABLE 4-7

Characteristics of Partnership Relations

- Have a long-term orientation
- Are strategic in nature
- Share information
- Share risks and opportunities
- Share a common vision
- Share short- and long-term plans
- Are driven by end-customer expectations

Benefits of Partnering

Early supplier involvement (ESI) Involvement of critical suppliers in new product design.

Early supplier involvement (**ESI**) is a natural result of partnering relationships and is one way to create impact. Critical suppliers become part of a cross-functional, new-product design team. These suppliers provide technical expertise in the initial phases of product design. Early involvement by suppliers often shortens new-product development time, improves competitiveness, and reduces costs. One example of early supplier involvement is Whirlpool Corporation's partnership with Eaton, a supplier of gas valves and regulators. Whirlpool used Eaton's design expertise to bring a new gas range to market several months sooner than it could have using Whirlpool's in-house design skills.

Ethics in Supply Management

A constant concern within purchasing departments is the issue of ethics in managing suppliers. Sales representatives from suppliers often offer buyers free lunches, free tickets to sporting or entertainment events, free weekend getaways, or valuable gifts. While suppliers may view these merely as promotional activities, at some point buyers need to consider how much is too much. Because buyers are in a position to influence or determine which supplier is awarded business, buyers must make certain that they avoid any appearance of unethical behavior or a conflict of interest.

Many companies have specific policies outlining what constitutes an acceptable gift or promotion. In some companies, buyers are not allowed to accept anything from a supplier, not even a pen. In other companies, there are dollar limits on what may be accepted. To guide purchasing employees, the Institute for Supply Management (ISM) has approved a set of principles and standards, which are shown in Table 4-8.

TABLE 4-8

ISM Principles and Standards of Ethical Supply Management Conduct

Reprinted with permission from the publisher, the Institute for Supply Management™, *Principles and Standards of Ethical Supply Management Conduct*, approved January 2002.

Loyalty to Your Organization / Justice to Those with Whom You Deal / Faith in Your Profession

From these principles are derived the ISM (Institute for Supply Management) global standards of supply management conduct.

1. Avoid the intent and appearance of unethical or compromising practice in relationships, actions, and communications.
2. Demonstrate loyalty to the employer by diligently following the lawful instructions of the employer, using reasonable care and granted authority.
3. Avoid any personal business or professional activity that would create a conflict between personal interests and the interests of the employer.

4. Avoid soliciting or accepting money, loans, credits, or preferential discounts, and the acceptance of gifts, entertainment, favors, or services from present or potential suppliers that might influence, or appear to influence, supply management decisions.
5. Handle confidential or proprietary information with due care and proper consideration of ethical and legal ramifications and government regulations.
6. Promote positive supplier relationships through courtesy and impartiality.
7. Avoid improper reciprocal agreements.
8. Know and obey the letter and the spirit of laws applicable to supply management.
9. Encourage support for small, disadvantaged, and minority-owned businesses.
10. Acquire and maintain professional competence.
11. Conduct supply management activities in accordance with national and international laws, customs and practices, your organization's policies, and these ethical principles and standards of conduct.
12. Enhance the stature of the supply management profession.

SUPPLY CHAIN DISTRIBUTION

The Role of Warehouses

Warehouses include plant, regional, and local warehouses. They can be owned or operated by the supplier or wholesaler, or they can be public warehouses. A further classification is general warehouse or distribution warehouse.

A **general warehouse** is used for storing goods for long periods with minimal handling. A **distribution warehouse** is used for moving and mixing goods. Within the supply chain, warehouses have three roles: transportation consolidation, product mixing or blending, and service. The business of a general warehouse is storage. The business of a distribution warehouse is movement and handling; therefore, the size of the facility is less important than its throughput. At a distribution warehouse, goods are received in large-volume lots and broken down into small individual orders.

▶ **General warehouse** Used for long-term storage.

▶ **Distribution warehouse** Used for short-term storage, consolidation, and product mixing.

A good example of the importance of distribution warehousing in support of e-commerce is Fingerhut's warehouse in St. Cloud, Minnesota. Employees rush through the warehouse on forklifts and cargo haulers filling orders for on-line retailers. Every item is encoded to speed packing. Red lasers scan each package as it rushes down the conveyor, verifying the actual package weight against expected package weight. Packages that do not

Courtesy Fingerhut

LINKS TO PRACTICE

Fingerhut Direct Marketing, Inc.
www.fingerhut.com

match are pushed aside for further inspection. The crew at this warehouse can process as many as 30,000 items per hour.

Transportation Consolidation occurs when warehouses consolidate less-than-truckload (LTL) quantities into truckload (TL) quantities. This consolidation can be both in supplier shipments to the manufacturer and in finished goods shipped to distant warehouses. The goal is to use TL shipments for as much of the distance as possible because TL shipments are cheaper than LTL shipments.

For inbound supplier shipments, a manufacturer can have small LTL deliveries from several suppliers consolidated at a convenient warehouse and then shipped to the manufacturer in TL shipments. For outbound shipments, the manufacturer can send TL deliveries to distant warehouses that break down the shipment for LTL delivery to local markets. Transportation consolidation is usually done to reduce transportation costs.

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Product Mixing is a value-added service for customers. With product mixing, the customer places an order to the warehouse for a variety of products. The warehouse groups the items together and ships the mixture of items directly to the customer. Without product mixing, the customer would have to place individual orders for each item and pay shipping for each item. Instead, product mixing enables quicker customer service and reduces transportation costs.

Services offered by the warehouses can improve customer service by moving goods closer to the customer and thus reducing replenishment time. For example, a tier one automotive supplier can use a warehouse located near an automotive assembly plant to store instrument panels. The producer requires the supplier to provide these instrument panels in VIN (vehicle identification number) order sequence within an hour. That means the warehouse must load and deliver the parts in the correct sequence to match the production as it occurs on the line, that is, right color, right style, right identification number, and so on.

▶ **Postponement**
A strategy that shifts production differentiation closer to the consumer by postponing final configuration.

Warehouses can also be used to finish custom products. For example, when manufacturers use **postponement** in their product design process, almost-finished products are delivered to the warehouse. When actual customer orders are received, the warehouse finishes the product according to the specifications of the customer. For example, in the furniture industry products can be left unstained until the customer order is received. The stain is then applied and the customer receives a custom product in minimal time. In the electronic industry, a unit may need to have the appropriate power supply and cord attached based on the location of the customer. Using the warehouse in this manner allows a manufacturer to maintain flexibility with almost-finished products and also to quickly provide a custom product for the customer.

Crossdocking

▶ **Crossdocking**
Eliminates the storage and order-picking functions of a distribution warehouse.

Crossdocking eliminates the storage and order-picking functions of a distribution warehouse while still performing its receiving and shipping functions. Trucks arrive at a crossdock with goods to be sorted, consolidated with other products, and loaded onto outbound trucks. Those trucks may be headed to a manufacturer, a retailer, or another crossdock. Shipments are transferred directly from inbound trailers to outbound trailers without any storage in between. Shipments should spend less than 24 hours in a crossdock.

What is the big difference between crossdocking and traditional distribution warehousing? In a traditional setting, the warehouse holds stock until a customer

places an order; then the item is picked, packed, and shipped. The customer typically is not known before the items arrive at the warehouse. With crossdocking, the customer is known before the items arrive at the warehouse and there is no reason to move the items into storage.

Crossdocking has two major advantages. First, the retailer reduces inventory holding costs by replacing inventory with information and coordination. Second, crossdocking can consolidate shipments to achieve truckload quantities and significantly reduce a company's inbound transportation costs.

Types of Crossdocking **Manufacturing crossdocking** is the receiving and consolidating of inbound supplies to support just-in-time manufacturing. In this case, the warehouse might be near the manufacturing facility and used to prep subassemblies or consolidate kits of parts. **Distributor crossdocking** is the receiving and consolidating of inbound products from different vendors into a multistock-keeping unit pallet that is delivered once the last product is received. **Transportation crossdocking** is the consolidating of shipments from LTL and small-package industries to gain economies of scale. **Retail crossdocking** is sorting product from multiple vendors onto outbound trucks headed for specific retail stores.

▶ **Manufacturing crossdocking** The receiving and consolidating of inbound supplies and materials to support just-in-time manufacturing.

▶ **Distributor crossdocking** The receiving and consolidating of inbound products from different vendors into a multi-SKU pallet.

▶ **Transportation crossdocking** Consolidation of LTL shipments to gain economies of scale.

▶ **Retail crossdocking** Sorting product from multiple vendors onto outbound trucks headed for specific stores.

Home Depot, Inc., Wal-Mart, Costco Wholesale Corporation, and FedEx Freight are examples of companies using crossdocking. At FedEx Freight, pickup and delivery drivers are busy during the day picking up freight that must be delivered that night and making deliveries. Each evening, drivers return to the crossdock. Freight is unloaded, sorted, and placed onto outbound trucks. The trucks travel through the night to their destinations, where the freight is unloaded and sorted onto local delivery trucks. FedEx Freight has achieved economies of scale that allow cost-effective transportation to areas with relatively little freight traffic.

David J. Sams/Stone/ Getty Images, Inc.

LINKS TO PRACTICE

FedEx Freight
www.fedexfreight.fedex.com

Radio Frequency Identification Technology (RFID)

Radio frequency identification (**RFID**) is an automated data collection technology. It uses radio frequency waves to transfer data between a reader and an RFID tag. The information is transmitted automatically so no one needs to unpack or scan individual bar code labels, yet it provides accurate data transmittal.

▶ **Radio frequency identification** (**RFID**) Unpowered microchips are used to wirelessly transmit encoded information through antennae.

The RFID tags contain encoded information that identifies items at the case, pallet, or container level. Rolls-Royce now uses RFID technology to track components used in military transport and combat aircraft and helicopters. In states with toll highways, RFID technology is used to collect tolls automatically. As a car with an RFID tag slowly passes through a collection lane, the RFID reader records the relevant vehicle data, and the appropriate toll charge is processed.

In a survey concerning RFID implementation, nearly half of consumer goods makers, a third of food and beverage makers, and a quarter of textile and apparel

manufacturers indicated that they were implementing RFID technology because of a mandate from Wal-Mart. The survey further indicated that 59 percent of companies in the automotive industry would deploy RFID technology during the coming year. Worldwide, RFID is forecasted to surpass $2.5 billion by 2010. There is some potential controversy regarding personal privacy in some possible future uses of RFID technology.

Third-Party Service Providers

The ease of developing an electronic storefront has allowed the discovery of suppliers from around the world. A good example is the success of artisans in Kenya, who by marketing over the Internet increased annual export earnings to $2 million from only $10,000. While smaller companies have benefited from these electronic storefronts, they often are not prepared to handle the logistics aspect. Many of these B2C companies outsource the delivery and return of products to companies such as FedEx and UPS. This works especially well when the consumer is paying for delivery.

A good example is Bike World, a company known for its high-quality bicycles, expert advice, and personalized service. After beginning Internet operations in 1996, Bike World found itself overwhelmed processing orders, manually shipping packages, and responding to customer inquiries regarding order status. Because of this, Bike World outsourced its order fulfillment to FedEx. FedEx offered reasonably priced delivery that exceeded customers' expectations.

Even larger companies often outsource their logistics. Consider when over 5400 CVS stores unveiled Gillette's Fusion, a new shaving product, all on the same day. Eight to ten weeks of planning was needed for this one-day event. The product was shipped to five of the CVS distribution centers. At the distribution centers, CVS coordinated pick-and-pack activities and readied the product for shipping to the stores. CVS used expedited shipping through a third-party logistics provider, delivering razors to all stores by noon that day. It was the first chain to have the new product available, providing it with increased market share.

IMPLEMENTING SUPPLY CHAIN MANAGEMENT

Implementing a strategic, integrated supply chain requires considerable effort on the part of the initiating company. This change often is a result of external pressures faced by the company, such as increased global competitors, an industry consolidation reducing the number of surviving companies in the industry, a switch to e-commerce (including e-purchasing and e-sourcing), or major technological changes within the industry.

Typically, a company begins by analyzing its current supply chain. A small cross-functional team leads the effort, examining all facets of the system to determine where improvements are possible and necessary. Most companies begin by looking at the parts of the supply chain, the internal dimension, in which they have the most control: manufacturing or service processes, distribution processes, and/or retail capacity and the time and costs of sourcing, producing, and distributing products or services. Improving performance in these areas has been the priority of many supply chain management initiatives. For a typical manufacturer, this means investing in automation and sales and operations planning technologies. For distributors and retailers, the priority has focused on supplier relationships, warehouse management, and transportation management solutions.

Some companies also include product design and supply chain design in the internal dimension. Supply chain design includes determining the best locations for manufacturing and warehousing facilities, as well as for retail outlets, and how to design the store itself. In global supply chains, companies also must decide whether or not to adopt offshore production. This decision now considers the traditional cost factors, such as production costs, distribution, and inventory, but also takes into account the greater risk of product damage and delay resulting from offshore production. Product design includes quality function deployment (QFD), ease of manufacturing, design for the environment (DFE), and ease of distribution throughout the supply chain.

The external dimension is that part of the supply chain that the company does not control. Predictable external factors include government regulations, mandates from trading partners, and environmental requirements. Often there is some advance notice of changes resulting from these factors. For example, a manufacturer can prepare itself to meet health, safety, or regulatory requirements such as the U.S. Food and Drug Administration (FDA) might apply to supply chains for food, drugs, and cosmetics. An example of a common trading partner mandate in the auto industry is the use of electronic data interchange (EDI) and membership in the net marketplace Covisint. If you want to be a supplier to an auto industry manufacturer, you must comply with these mandates. When integrating the external supplier base, many companies develop supplier relationships.

The requirement to use radio frequency identification device (RFID) technology is occurring in consumer goods and retail supply chains. Environmental considerations include restrictions on the discharge of solid, liquid, and gaseous waste. The supply chain can accommodate these predictable or expected external factors.

The external dimension also includes actions that are very difficult to predict and can devastate an organization. A sudden spike in fuel prices, worker strikes, delays in shipping due to customs noncompliance, port congestion, and major weather-related disasters can put considerable stress on the supply chain. Any problems that occur inside the supplier's or the distributor's supply chain also can lead to delays in sourcing, production, and movement of finished products, which threaten supply continuity and the quality of service to the final customer. To meet such challenges, companies need to improve their supply chain visibility so that real-time responses can be made to minimize the chance of disruption.

The customer dimension is where your company may have some influence but does not have total control. Ways to influence the customer include offering customers the features and functions they want, when they want them, and at an attractive price. Companies also can use promotional strategies to shape demand to better meet their business goals. Supply chains can typically provide better customer service when better product demand information is available to all members of the chain. This can be done using point-of-sale (POS) technology. Let's look at some strategies to leverage your supply chain.

Strategies for Leveraging Supply Chain Management

Although implementing supply chain management requires a set of actions that are unique to every company, the end goal is the same. Companies want a supply chain that makes it possible to manage and adapt to all of the business dynamics affecting the company. This includes improving insight and control over your own internal operations; catering to, influencing, and responding faster to events beyond your control; and focusing on the customer and demand signals that affect your supply chain. You should consider each of the following actions.

1. You should regularly assess your supply chain network to make sure it is still suited for your business. Make sure that you are not making adjustments to a supply chain that is no longer suitable for meeting your current and future business needs. Many supply chains merely evolve over time or through acquisitions. They are not designed but rather worked around. Take time to make sure your network fits your needs. Long-term profitability depends on having the right capacity and the right location of your physical assets.
2. You should have a global view of demand. You need to anticipate demand and take opportunities to influence it to reach your financial objectives. Using a collaborative demand planning solution (discussed in Chapter 8) is a good way to develop a global view of demand. You need visibility into customer buying patterns so that you can determine appropriate inventory, production, sourcing, and distribution plans.
3. You should decide how to get products to your customers. You decide what to make or buy; whether to build products in America, Europe, or elsewhere; which distribution center to provide the product to the customer; and how much inventory to hold and where.
4. You should improve asset productivity. For manufacturers, better demand visibility allows for effective planning and scheduling to maximize returns on critical assets, such as equipment, materials, and people. For logistics providers and retailers, the reduced uncertainty allows more effective use of warehousing and transportation assets.
5. You should expand your visibility. In global supply chains, product travels more miles, passes through more hands, and crosses more systems on its way to the final customer. There are numerous points where a disruption can occur. The use of RFID technology can provide real-time visibility into inventory status regardless of where it is and improve your ability to predict and plan for its arrival.
6. You need to know what happens, when it happens. For you to minimize the effect of an external event or to maximize the opportunity of new customer demand, you need to know about it as early as possible so that you can take the appropriate action. For example, if you learn immediately when a manufacturer has a major production problem, you can possibly allocate some production to another factory within the supply chain. If you learn immediately of increased customer demand in a specific region, you may be able to meet this demand by rerouting product as it moves through the supply chain.
7. You need to design to deliver. A holistic view of the supply chain must include the design of the product itself. Focus on ways to reduce development time and time to market. Consider whether it makes sense to use a third-party logistics provider for last-minute product customization. The postponement approach provides flexibility, as well as removing costs from manufacturing. It often allows for delivery of the final configured product within 24 hours to the customer. If a company wants to use a postponement approach, it must be considered during the product design.
8. You must track performance to allow for continuous improvement.

Implementing these strategies should result in benefits for members of the supply chain. You should reduce operations expenses. Having a clearer picture of end-customer demand allows companies to better plan for the appropriate mix of inven-

tory, production, and transportation strategies. The companies should expect improved profitability as internal operations become more efficient and cost effective. Customer service should be improved since the companies have better visibility into final customer demand. Competitiveness and faster growth should improve as the company gains better insight into the internal, external, and customer dimension of its business.

Eliminating Waste in the Supply Chain

While the previous section discussed strategies for implementing an integrated supply chain, this section discusses seven potential sources of waste in a supply chain, as shown in Table 4-9.

The first source of waste is overproduction. Don't build product before it is needed. Remember our earlier discussion of the bullwhip effect and how it distorts demand information. The remedies for the bullwhip effect can help the company not build more than what is needed or build it before it is needed.

The second source of waste is any delay between the end of one activity and the start of the next. A good example is the time between the arrival of a truck for a pickup and the actual loading of the trailer. Another example is the amount of delay between the receipt of a customer's order information and the actual beginning of the work needed to fulfill the order. Additional delays occur when a company misses a shipping cutoff time. Many third-party providers like FedEx and UPS have cutoff times at the end of the day that must be met if you want the product to ship. If you miss the deadline, the product does not ship until the next scheduled shipment. While this may result in only a single-day delay, think about what happens if you are shipping a product across the ocean and you miss the cutoff date. The product may wait for a week or longer for the next ship to depart. Any delay merely adds to the lead time for the supply chain.

The third source of waste is the unnecessary transport or conveyance of product. This includes both internal movement within a facility and external movement between facilities. A particular concern is poor use of transport capacity—that is, shipping items in less than full truck loads, having trucks make out-of-route stops, and having trucks return empty. Remember the example discussed earlier in this chapter about the possible impact when the instrument panel producer and the automobile manufacturer were both able to improve transportation efficiency by eliminating empty backhauls.

The fourth source of waste is unnecessary movement by people, such as walking, reaching, and stretching. Waste of motion also includes extra travel or reaching due to

TABLE 4-9

Supply Chain Waste

1. Overproduction. Build first, then wait for orders.
2. Any delay or waiting between the end of one activity and the start of the next activity.
3. Any unnecessary transportation or conveyance.
4. Any kind of unnecessary movement by people.
5. Any activity that results in more inventory than needed.
6. Any suboptimal use of space.
7. Any errors that cause more work.

poor storage arrangement or poor ergonomic design of the work area. One example of poor storage arrangement is the placement of a frequently used inventory item in the back portion of a warehouse rather than up front. This maximizes the distance walked to retrieve the item each time it is requested.

The fifth source is any activity that results in more inventory being positioned than is needed or in a location other than where it is needed. Examples include early deliveries, receipt of a quantity greater than needed, and inventory being sent to the wrong place. With improved demand data, less uncertainty in the supply chain, and lower transaction costs, inventory investment should be reduced throughout the supply chain.

The sixth source of waste is suboptimal use of space, whether it be trailer loads, cartons that are not filled to capacity, inefficient use of warehouse space, and loads exceeding capacity. For a good example of cartons not filled to capacity, think of containers of parts sitting on warehouse shelves that have been opened and have had some parts removed, but the carton remains on the shelf and still takes up the same amount of shelf space. Think also of what happens when different quantities of an item are ordered. The allotted shelf space must be great enough for the highest quantity ordered. When lesser quantities are purchased, the space is not fully used.

The seventh source of waste is errors that cause rework, unnecessary adjustments or returns, such as billing errors, inventory discrepancies and adjustments, and damaged/defective/mislabeled product. It is never cheaper to fix a problem or mistake than it is to do it right the first time. Scanners can be used to eliminate some human errors, but attention to process design is needed to reduce human error.

SUPPLY CHAIN PERFORMANCE METRICS

A company can use traditional financial measures such as return on investment (ROI), profitability, market share, and revenue growth, as well as traditional inventory performance measures such as customer service levels, inventory turns, weeks of supply, and inventory obsolescence (all discussed in Chapter 12).

Let's look at how a large state university used several metrics to analyze how well its supply chain achieved the following initiatives. The first initiative was a spend analysis. This was a strategic review of spend data across all purchase and payment methods to increase compliance and identify new organization-specific contracting and cost containment opportunities. The university also evaluated its level of progress in strategic sourcing. The purpose of the supply base management initiatives was to leverage the university's buying power and maximize the value of its strategic supplier business relationships. A third initiative concerned contract management. This initiative concerned the development and implementation of a university-wide best-in-class contract pricing agreement that would assure the university the "least total cost" for products and services required from external suppliers. The fourth initiative evaluated the use of collaborative buying. This examined how well the university had used local, regional, and national collaborative buying business partners to further leverage buying power. The last initiative was concerned with compliance. It was designed to promote faculty and staff compliance with procurement and disbursement financial policies and to determine the level of compliance to university-authorized buying methods and use of contract suppliers. To summarize, the university analyzed the frequency with which members of its supply chain were used, while simultaneously checking to see if new suppliers should be added to its supply chain.

The university also used a number of key purchasing performance metrics. The *financial metric* measured ROI, the total cost containment versus the operating budget, the combination of cost savings and supply chain revenue, the negotiated product and service cost savings, and purchasing revenue. The *contracting metric* looked at the number of new preferred discount contracts, the level of spending done with contract suppliers, the amount of collaborative buying, the number of electronic competitive bidding events, and the number of strategic sources deactivated. The compliance metric also considered the level of purchase order buys and the level of buys through managed supplier relationships, the level of purchase activity at the university's net marketplace and the use of marketplace suppliers, and the amount of green product and service purchases.

An analysis of the e-marketing summarized the number of unique visitors to the purchasing services Web site and to the supplier showcase. Operations were analyzed based on the percentage of customers very satisfied in a biannual survey. Economic inclusion measured the amount of buys placed with local community-based suppliers. It also analyzed the amount of purchases made with all diversity-owned suppliers, as well as all African American-owned suppliers. The number of diversity suppliers in the university marketplace was also monitored. The university used purchasing cards (p-cards) for staff to place small purchases without the need for a purchase order. The level of use of p-cards was tracked to determine the level of noncompliance with commodity or supplier restrictions. Travel expenses were also monitored to determine compliance with negotiated travel service providers. And finally, the university measured accounts payable activities, such as the percentage of electronic purchase order invoices, the effectiveness of the electronic invoice business process (EDI), the number of data errors causing rejections, the percentage of supplier invoices paid within terms, and the use of electronic fund transfers (EFT). Clearly, the number of specific metrics used by the university is quite significant. Other activities to analyze can include quality and on-time delivery of products and services.

Organizations also often measure the quality of their products or services. An organization can measure product or service quality by looking at warranty costs, products returned, and markdowns given to the customer due to poor quality or service. In Chapters 5 and 6, you will learn about different aspects of quality and methods for measuring quality levels. These techniques can easily track supply chain quality.

In Chapter 15, you will learn about scheduling performance measures that could be used to evaluate the company's response time as well as to evaluate how well the company is using its capacity. Excess capacity may enable much quicker response times, but the company must assess the cost of low capacity utilization.

The company needs to determine what customer satisfaction means to its customers. Does it mean filling the entire order? Does it mean how quickly it can respond to customer requests? Or is it more important to have the product always arrive on time? Answering these questions identifies the activities that support the supply chain's objectives. These are the activities that must be measured.

An example of manufacturing performance metrics was reported in a study of U.S.–Mexican maquiladora operations. Performance measurements included cycle-time reduction (response time), routing and scheduling performance (on-time delivery, response time, and capacity utilization), and outbound cross-border transportation. The bottom line is that companies must measure performance of the supply chain and the measurements must support behavior that is consistent with the supply chain objectives.

The Supply Chain Operations Reference (SCOR) model is an effort to standardize measurement of supply chain performance. The SCOR model examines four different operational perspectives: reliability, flexibility, expenses, and assets/utilization. From a reliability perspective, the supply chain is measured on on-time delivery, order

fulfillment lead time, and fill rate (the fraction of demand met from stock). In terms of flexibility, supply chain response time and production flexibility are measured. For expenses, supply chain management cost, warranty cost as a percentage of revenue, and value added per employee are examined. In terms of assets/utilization, total inventory days of supply, cash-to-cash cycle time, and net asset turns can be measured.

TRENDS IN SUPPLY CHAIN MANAGEMENT

The past few years have seen increased use of electronic marketplaces that bring thousands of suppliers together with thousands of buyers. The objectives of these net marketplaces are to have suppliers compete on price, to encourage automated low-cost transactions, and to reduce the price of industrial supplies.

▶ **E-distributors**
Independently owned net marketplaces having catalogs representing thousands of suppliers and designed for spot purchases.

E-distributors are the most common form of net marketplace. E-distributors provide electronic catalogs representing the products of thousands of suppliers. E-distributors are independently owned intermediaries that provide a single source for customers to make spot purchases. About 40 percent of a company's items are purchased on a spot basis. E-distributors typically have fixed prices but do offer quantity discounts to large customers (see Chapter 12). The primary benefits of e-distribution to the manufacturing company are lower product search costs, lower transaction costs, a wide selection of suppliers, rapid product delivery, and low prices.

▶ **E-purchasing**
Companies that connect on-line MRO suppliers to businesses that pay fees to join the market, usually for long-term contractual purchasing.

▶ **Value chain management (VCM)**
Automation of a firm's purchasing or selling processes.

E-purchasing companies connect on-line suppliers offering maintenance, repair parts, and operating supplies (MRO) to businesses that pay fees to join the market. E-procurement companies are typically used for long-term contractual purchasing and offer value chain management services to both buyers and sellers. **Value chain management (VCM)** automates a firm's purchasing or selling processes. VCM automates purchase orders, requisitions, product sourcing, invoicing, and payment. For suppliers, VCM automates order status, order tracking, invoicing, shipping, and order corrections.

▶ **Exchanges**
A marketplace that focuses on spot requirements of large firms in a single industry.

On-line **exchanges** connect hundreds of suppliers to unlimited buyers. Exchanges create a marketplace focusing on spot requirements of large firms in a single industry, such as the automotive industry or electronics industry. Examples of exchanges include ProcureSteel.com (a market for steel products), e-Greenbiz.com (spot market for nursery supplies), and Smarterwork.com (professional services from Web design to legal advice).

▶ **Industry consortia**
Industry-owned markets that enable buyers to purchase direct inputs from a limited set of invited suppliers.

The last type of net marketplace is an industry consortium. **Industry consortia** are industry-owned markets that enable buyers to purchase direct inputs from a limited set of invited participants. The objective of an industry consortium is the unification of supply chains within entire industries through a common network and computing platform. Examples of industry consortia include Covisint.com (automotive industry), Avendra.com (hospitality industry), and ForestExpress.com (paper and forest products). It is clear that net marketplaces will be a dominant factor in effective supply chain management now and in the future. Technology continues to bring suppliers, buyers, and distributors closer together so that supply chains can be managed effectively.

▶ **Supply chain velocity**
The speed at which product moves through a pipeline from the manufacturer to the customer.

As supply chains cover greater distances, they experience greater uncertainty and generally are less efficient. It is likely that **supply chain velocity** in these global chains will decrease. Practitioners have identified the following characteristics associated with lower-velocity supply chains: lumpy supply/demand (goods tend to arrive at the warehouse in large quantities and sometimes without notice), more break-bulk activity because of the larger quantities, slower long-distance moves as companies source offshore, and higher inventory levels in the pipeline due to longer transit times. These

lower-velocity supply chains raise additional questions, such as distribution center location or a better understanding of the economics of break-bulk and more emphasis on pipeline design.

Without a doubt, one of the most important issues facing supply chain managers is how to green the supply chain. The issues of packaging, final product disposition, and the supply chain carbon footprint are significant concerns facing all supply chains.

As you can see, a number of issues still remain for supply chain managers. The only clear trend is that information technology will be a primary enabler of successful supply chain management.

SUPPLY CHAIN MANAGEMENT WITHIN OM: HOW IT ALL FITS TOGETHER

Supply chain management (SCM) is directly linked to many OM activities. The degree of supply chain management is a strategic decision for the organization (Chapter 2) and determines the level of vertical integration in the organization. SCM is concerned with external suppliers, internal operations, and external distributors.

Effective SCM requires supplier partnerships. Using the ISM Principles and Standards of Ethical Supply Management Conduct, purchasing develops partnerships with suppliers to assure a continuous supply of materials at a reasonable cost. Purchasing also works with suppliers to improve communications, to develop flexibility in meeting changes of demand, to improve quality of materials, and to assure on-time delivery. This assured, continuous supply of materials allows the production planners to effectively schedule jobs (Chapter 14) and to use equipment and personnel efficiently.

SCM also provides for streamlined communications between suppliers and the company, thus reducing purchasing lead time. As we will learn when studying inventory management in Chapter 12, reduced lead time results in lower inventory levels. The improved communications within the supply chain improve demand forecasting accuracy. This reduces demand uncertainty, allowing lower safety stock investment while still maintaining customer service levels. Improved demand forecast accuracy also contributes to the development of better staffing plans (Chapter 13), which can lead to lower personnel costs, lower inventory costs, and improved customer service.

SCM affects product and process design (Chapter 3) by specifying which items are done in-house and which items are outsourced. Good supply chain management provides timely, accurate information that is critical to successful operations management.

SCM ACROSS THE ORGANIZATION

Supply chain management changes the way companies do business. Consider how supply chain management affects different functional areas within the organization.

Accounting shares some of the benefits and responsibilities of supply chain management. As inventory levels decrease, customer service levels increase. Accounting is exposed to the risks of information sharing and involved in developing long-term partnerships. With information sharing comes the need for increased confidentiality and trust.

Marketing benefits by improved customer service levels achieved by POS data collection. A shared database provides marketing with current demand trends and eliminates demand filtering between levels of the supply chain. POS data also facilitate quicker customer response time.

Information systems are critical for supply chain management. Information systems provide the means for collecting relevant demand data, developing a common

database, and providing a means for transmitting order information. Information systems enable information sharing through POS data, EDI, RFID, the Internet, intranets, and extranets.

Purchasing has an important role in supply chain management. Purchasing is responsible for sourcing materials and developing a strong global supplier base through long-term partnering agreements, using e-sourcing and e-purchasing concepts.

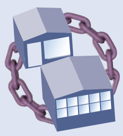
OM

Operations uses timely demand information to more effectively plan production schedules and use manufacturing capacity. Operations responds more quickly to changing customer demand data, thus providing improved customer service levels.

Who is responsible for supply chain management within an organization? In a manufacturing company, it is often the materials manager, since he or she is more familiar with external suppliers, internal functions, and external distributors. The person who does supply chain management must see the "big picture" so that local priorities do not overshadow global priorities. In a service organization, the operations or office manager may be responsible for supply chain management.

THE SUPPLY CHAIN LINK

This chapter provides the framework for understanding supply chain management. Supply chains consist of external suppliers, internal processes, and external distributors. Internal processes (purchasing, processing, production planning and control, quality assurance, and shipping) are integrated first since the manufacturer has direct control over these activities. Integrating external suppliers into the supply chain begins with sourcing decisions and subsequent strategic partnership development by the purchasing function. Electronic net marketplaces facilitate sourcing by bringing together thousands of suppliers and buyers to a common site. Distributors are usually the last segment of the chain to be integrated. Warehouses can be used for consolidation, product mixing, or finalizing products. Crossdocking can reduce transit time as well as reduce handling of goods. RFID helps track materials as they flow through the supply chain. POS demand data are provided to all members of the supply chain to reduce uncertainty and to assure that all members of the supply chain work with common data.



Chapter Highlights

1. Every organization is part of a supply chain, either as a customer or as a supplier. Supply chains include all the processes needed to make a finished product, from the extraction of raw materials through to the sale to the end user. Supply chain management is the integration and coordination of all these activities.

2. The bullwhip effect distorts product demand information passed between levels of the supply chain. The more levels that exist, the more distortion that is possible. Variability results from updating demand estimates at each level, order batching, price fluctuations, and rationing.

3. Supply chains for service organizations can also have external suppliers, internal processes, and external distributors. The supply chain for a travel agency requires the agent to plan, arrange, schedule, and invoice travel by using potential travel service providers and then subsequently allowing those service providers to perform the actual travel-related service.

4. Many issues affect supply chain management. The Internet, the Web, EDI, intranets, extranets, bar code scanners, and POS data are supply chain management enablers. Technology advancements facilitate information sharing among supply chain members. Intranets and extranets improve communication flow within organizations and supply chains. Through the use of electronic net marketplaces, the Internet greatly reduces the cost of researching suppliers. Customer expectations are high as they demand better service, better product quality, quicker response times, reasonable prices, and an easy way to return merchandise.

5. B2B and B2C electronic commerce enable supply chain management. Net marketplaces bring together thousands of suppliers and customers, allowing for efficient sourcing and lower transaction costs.

6. Global supply chains often face greater uncertainty, potentially slowing the supply chain velocity and increasing supply chain inventory levels. Inadequate infrastructure can also complicate global supply chains.

7 Government regulations affecting supply chain management center on intellectual property rights and conformance with copyright laws. The Internet structure makes it difficult for governments to enact many regulations at this time.

8 Green supply chain management focuses on the environment and how anything done in the supply chain affects the environment. Supply chains try to reduce their carbon footprint and become more environmentally friendly.

9 Purchasing has a major role in supply chain management. Purchasing is involved in sourcing decisions and developing strategic long-term partnerships. Purchasing develops and maintains a supplier base capable of assuring material availability, timely delivery performance, high-quality products, and reasonable prices.

10 Sourcing is critical in establishing a solid, responsive supplier base. The use of net mareketplaces has allowed companies to reduce supplier search costs and facilitated the use of e-sourcing. Companies make insourcing and outsourcing decisions. These make-or-buy decisions are based on financial and strategic criteria. Companies typically do not outsource activities that are part of their core competencies.

11 Partnerships require sharing information, risks, technologies, and opportunities. Impact, intimacy, and vision are critical to successful partnering. Impact means attaining higher levels of productivity and competitiveness that are not possible through normal supplier relationships. Intimacy requires trust as companies share confidential information. Vision means having common objectives.

12 Ethics in supply management is an ongoing concern. Since buyers are in a position to influence or award business, it is imperative that they avoid any appearance of unethical behavior or conflict of interest. The Institute for Supply Management has established a set of principles and standards to guide buyers.

13 Supply chain distribution requires effective warehousing operations. The warehouses provide transportation consolidation, product mixing, and service. Warehouses consolidate (LTL) quantities into (TL) quantities. Product mixing adds value for the customer because the warehouse groups the items and ships them directly to the customer. Warehouses can improve customer service by placing goods closer to the customer to reduce response time. Crossdocking is an effective method for reducing transportation costs. RFID is gaining use as a means of accurately tracking shipments. Much of the distribution function has been outsourced to third-party logistics providers.

14 Implementing supply chain management usually begins with the manufacturer integrating internal processes first. Then, the company tries to integrate the external suppliers. The last step is integrating the external distributors.

15 A company needs to evaluate the performance of its supply chain. Regular performance metrics (ROI, profitability, market share, customer service levels, etc.) and other measures that reflect the objectives of the supply chain are used. In addition, the company can use the Supply Chain Operations Reference (SCOR) model to standardize its supply chain performance.

16 The emergence of net marketplaces has significantly affected supply chain management. As supply chains become longer, it is likely that supply chain velocity will decrease. It is possible that a more strategic and integrated approach is needed to advance supply chain management to the next level. Such an approach will combine world-class supply chain management, process leadership in lean manufacturing techniques, and "on-demand" information technology.

Key Terms

supply chain 99
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tier one supplier 102
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tier three supplier 102
logistics 103
traffic management 103
distribution management 103
bullwhip effect 103
e-commerce 107
business-to-business e-commerce (B2B) 107
automated order entry system 107
electronic data interchange (EDI) 107
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Formula Review

For insourcing or outsourcing:

$$FC_{\text{Buy}} + (VC_{\text{Buy}} \times Q) = FC_{\text{Make}} + (VC_{\text{Make}} \times Q)$$

Solved Problems

(See student companion site for Excel template.)

• Problem 1

Jack Smith, owner of Jack's Auto Sales, is deciding whether his company should process its own auto loan applications or ousource the process to Loans Etc. If Jack processes the auto loan applications internally, he faces an annual fixed cost of $2500 for membership fees, allowing him access to the TopNotch credit company, and a variable cost of $25 each time he processes a loan application. Loans Etc. will process the loans for $35 per application, but Jack must lease equipment from Loans Etc. at a fixed annual cost of $1000. Jack estimates processing 125 loan applications per year. What do you think Jack should do?

(a) Should Jack process the loans internally or outsource the loans if demand is expected to be 125 loan applications?
(b) Is Jack indifferent to internal processing and outsourcing at one level of loan applications?

• *Before You Begin:*

To make his decision when demand is known, Jack needs to calculate the total cost of processing the auto loans in-house and compare it to the total cost of outsourcing the loan processing. You need to identify the relevant costs. If Jack processes the loans internally, he has an annual fixed cost of $2500 plus a per loan variable cost of $25. If the loan processing is outsourced, Jack has a fixed annual cost of $1000 and a per loan variable cost of $35.

• *Solution*

(a) The total cost for processing 125 loan applications internally is $5625. That is $2500 in annual fixed costs plus 125 loan applications multiplied by the $25 per application variable cost. The total cost for outsourcing the applications is $5375. That is $1000 in annual fixed costs plus 125 loan applications multiplied by the $35 per application variable cost. At 125 loan applications, it is cheaper for Jack to outsource the loan application processing.
(b) When demand is not known, set the total costs of each alternative equal to each other, or $\$1000 + (\$35 * Q) = \$2500 + (\$25 * Q)$. Solving for Q, we have $10Q = \$1500$, or $Q = 150$ loan applications. Since the costs are equal at 150 loan applications and Jack expects to need 125 applications processed, he is better off outsourcing the loan applications to Loans Etc.

• Problem 2

Big State University (BSU) is considering whether or not it should outsource its housekeeping service. Currently, BSU employs 400 housekeepers at an average annual wage of $23,000 plus another 39 percent for fringe benefits. Annual fixed costs associated with housekeeping are $1,278,800.

Eric's Efficient Cleaners (EEC) will provide similar housekeeping for a fixed annual cost of $7,500,000 plus a variable cost of $20,000 per housekeeper required. Because Eric uses state-of-the-art equipment and well-trained employees, his company would need only 80 percent of the current BSU housekeeper staff (or 320 housekeepers).

(a) Calculate the annual cost of BSU using its current housekeeping staff.
(b) Calculate the annual cost if BSU lets EEC do the housekeeping.
(c) Find the indifference point for the two alternatives.

• *Before You Begin:*

Identify the relevant costs. You need to know the cost to BSU for using its own housekeeping staff. The average annual salary per housekeeper is $23,000 plus fringe benefits (39 percent of the average annual salary). The annual fixed cost associated with housekeeping is $1,278,800. If housekeeping is outsourced, BSU doesn't need to pay fringe benefits. EEC will provide similar service for a fixed annual cost of $7,500,000 plus a variable cost of $20,000 per housekeeper. Remember that he only needs 320 housekeepers for the job.

• ***Solution***

(a) If BSU does its housekeeping with its current staff, the cost is $14,066,800.

Cost per housekeeper ($23,000 + 39% fringe benefits) = $31,970

Cost for 400 housekeepers (400 × $31,970)	=	$12,788,800
Annual fixed costs	=	°1,278,000
Total annual costs		$14,066,800

(b) If BSU has EEC do the housekeeping, the cost is $13,900,000.

Cost for 320 housekeepers (320 × $20,000)	=	$ 6,400,000
Annual fixed costs	=	°7,500,000
Total annual costs		$13,900,000

(c) The indifference point is found by setting the two cost functions equal to each other. Since EEC only needs 80% as many employees as BSU, we need to adjust the cost functions.

$$\$1{,}278{,}800 + \$31{,}970(Q) = \$7{,}500{,}000 + (0.8Q)(\$20{,}000)$$

Q = 389.55, or 390 employees. Therefore, if the school needs fewer than 390 in-house housekeepers, it should do the housekeeping rather than outsource it. If BSU needs more than 390 housekeepers, it should outsource with EEC.

Discussion Questions

1. Discuss the different types of e-commerce.
2. Explain the different revenue models used in e-commerce.
3. Give two examples from the Internet for each of the different revenue models used in e-commerce.
4. Describe the evolution of business-to-business (B2B) e-commerce.
5. For the next item you buy, determine its supply chain.
6. How do supply chains for service organizations differ from supply chains for manufacturing organizations?
7. How can companies satisfy increasing customer expectations?
8. Describe the additional factors that affect global supply chains.
9. Think of your last major purchase. What criteria did you use to select the supplier?
10. Explain the concept of partnering, including advantages and disadvantages.
11. Explain the benefits of using a single supplier as opposed to multiple suppliers.
12. Describe the kinds of information that are necessary in a supply chain.
13. Describe the role of warehouses in a supply chain.
14. Describe radio frequency identification (RFID) and how it could be used by an organization.
15. Describe the current trends in e-commerce and how they affect supply chain management.

Problems

1. Gabriela Manufacturing must decide whether to insource or outsource a new toxic-free miracle carpet cleaner that works with its Miracle Carpet Cleaning Machine. If it decides to insource the product, the process would incur $300,000 of annual fixed costs and $1.50 per unit of variable costs. If it is outsourced, a supplier has offered to make it for an annual fixed cost of $120,000 and a variable cost of $2.25 per unit in variable costs.
   (a) Given these two alternatives, determine the indifference point (where total costs are equal).
   (b) If the expected demand for the new miracle cleaner is 300,000 units, what would you recommend that Gabriela Manufacturing do?

2. Gabriela Manufacturing was able to find a new supplier that would provide the item for $1.80 per unit with an annual fixed cost of $200,000. Should Gabriela Manufacturing insource or outsource the item?

3. Downhill Boards (DB), a producer of snow boards, is evaluating a new process for applying the finish to its snow boards. Durable Finish Company (DFC) has offered to apply the finish for $170,000 in fixed costs and a unit variable cost of $0.65. Downhill Boards currently incurs a fixed annual cost of $125,000 and has a variable cost of $0.90 per unit. Annual demand for the snow boards is 160,000.
   (a) Calculate the annual cost of the current process used at Downhill Boards.
   (b) Calculate the annual cost if Durable Finish Company applies the finish.
   (c) Find the indifference point for these two alternatives.
   (d) How much of a change in demand is needed to justify outsourcing the process?

4. Fast Finish, Inc. (FFI) has made a technological breakthrough in snow board finish application. FFI will apply the finish for $0.23 per unit in variable costs plus a fixed annual cost of $230,000. Use the cost and demand information given in Problem 3 for Downhill Boards to evaluate this proposal.
   (a) What will it cost Downhill Boards to outsource the finishing process?
   (b) At what demand level does it make sense economically to outsource the finishing process?

(c) What additional factors should be considered when making this outsourcing decision?

5. Henri of Henri's French Cuisine (HFC), a chain of 12 restaurants, is trying to decide if it makes sense to outsource the purchasing function. Currently, Henri employs two buyers at an annual fixed cost of $85,000. Henri estimates that the variable cost of each purchase order placed is $15. Value-Buy (VB), a group of purchasing specialists, will perform the purchasing function for a fixed annual fee of $100,000 plus $5 for each purchase order placed. Last year, HFC placed 1450 purchase orders.

(a) What was the cost last year to HFC when doing the purchasing in-house?
(b) What would the cost have been last year had HFC used Value-Buy?
(c) What is the indifference point for the two alternatives?
(d) If HFC estimates it will place 1600 purchase orders next year, should it use VB?
(e) What additional factors should be considered by HFC?

6. Cal's Carpentry is considering outsourcing its accounts receivable function. Currently, Cal employs two full-time clerks and one part-time clerk to manage accounts receivable. Each full-time clerk has an annual salary of $36,000 plus fringe benefits costing 30 percent of their salary. The part-time clerk makes $18,000 per year but has no fringe benefits. Total salary plus fringe cost is $111,600. Cal estimates that each account receivable incurs a $10 variable cost. The Small Business Accounts Receivables Group (SBARG) specializes in handling accounts receivable for small- to medium-size companies. Doris Roberts from SBARG has offered to do the accounts receivable for Cal's Carpentry at a fixed cost of $75,000 per year plus $30 per account receivable. Next year, Cal expects to have 2000 accounts receivable.

(a) Calculate the cost for Cal's Carpentry to continue doing accounts receivable in-house.
(b) Calculate the cost for Cal's Carpentry to use SBARG to handle the accounts receivable.
(c) If the fixed annual cost offered by SBARG is nonnegotiable but it is willing to negotiate the variable cost, what variable cost from SBARG would make Cal indifferent to the two options?
(d) What other alternatives might Cal consider in terms of his current staffing for accounts receivable?
(e) What additional criteria should Cal consider before outsourcing the accounts receivable?

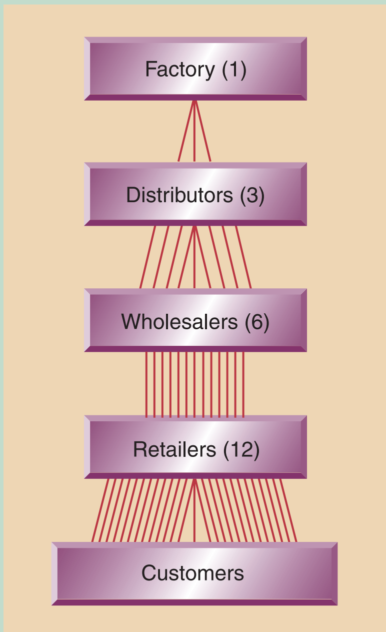
CASE: Electronic Pocket Calendars Supply Chain Management Game

In this supply chain game, retailers sell electronic pocket calendars to their customers and place replenishment orders to their wholesaler. The wholesaler sells the pocket calendars to the retailers and orders the calendars from a distributor. The distributor sells the pocket calendars to the wholesalers and orders calendars directly from the factory. The distribution system is shown in the figure. For each period the game is played, participants must follow the same sequence:

1. Receive any shipments into inventory.
2. Ship calendars to satisfy both new customer demand and any back orders, as long as sufficient product is available.
3. Determine the ending inventory (a negative value indicates back orders exist).
4. Determine the inventory position (ending inventory plus any quantity already ordered).
5. Place replenishment orders.

For this game, inventory holding costs will be $10 per case per week and back order costs will be $15 per case per week.

Each person must keep track of his or her own costs. The weekly demand at the retailers will be provided by your professor. Once the demand is known by the retailers, the retailers place the appropriate replenishment orders with the wholesalers. The wholesalers update their inventory records and place the necessary orders with the distributor. At this point, the distributor updates its inventory records and places the appropriate replenishment order with the factory. Lead time throughout the supply chain is two weeks. For example, once the factory releases an order to be manufactured, it is two weeks before it is available; when the distributor orders pocket calendars from the factory, it is two weeks before they arrive.



Electronic pocket calendar supply chain

Individual Location Information

	Replenishment Order Quantity (cases)	Reorder Point (cases)	Beginning Inventory (cases)	Average Weekly Demand (cases)
Factory	350	190	277	175
Distributor A	120	125	185	60
Distributor B	180	190	280	90
Distributor C	100	52	77	25
Wholesaler A1	90	95	140	45
Wholesaler A2	60	31	46	15
Wholesaler B1	105	110	163	52.5
Wholesaler B2	75	80	118	37.5
Wholesaler C1	60	31	46	15
Wholesaler C2	40	21	31	10
Retailer A11	60	62	92	30
Retailer A12	30	31	46	15
Retailer A21	45	24	35	11.25
Retailer A22	15	8	13	3.75
Retailer B11	75	78	116	37.5
Retailer B12	60	31	46	15
Retailer B21	40	42	62	20
Retailer B22	35	37	55	17.5
Retailer C11	40	21	31	10
Retailer C12	20	11	16	5
Retailer C21	20	12	18	5.5
Retailer C22	20	10	15	4.5

A number of participants are needed in this game (see the figure). One person manages the factory (1). There are three distribution centers, each needing a manager (3). Each distribution center supplies two different wholesalers (6), and each wholesaler supplies two unique retailers (12). In some cases, a location may have co-managers to speed up the transactions. The accompanying table provides information regarding each location in the supply chain.

For each period of the game, retailers follow these procedures:

1. The retailer accepts into stock any orders due to arrive during the current period. The beginning inventory plus the arriving order determine how much inventory the location has available to satisfy demand during that period.

2. Next, your professor provides each retailer with actual demand data for that period. The demand is given to the retailer on a paper order form. The data are not shown to other members of the supply chain but are treated as confidential information.

3. Retailers fill orders as long as sufficient inventory (calculated in Step 1) is available.

4. Retailers calculate their ending inventory level. If sufficient inventory is available, ending inventory is beginning inventory minus that period's actual demand. If there is not sufficient inventory, then back orders occur. When a back order occurs, your ending inventory value is negative. For example, if you only have 30 units available and demand is 32 units, your inventory balance is −2 units.

5. Retailers calculate their inventory position. Inventory position is the ending inventory plus any quantity already ordered that has not yet arrived. For example, if your ending inventory is −2 but you have placed an order for 90 additional cases, your inventory position is 88 cases (−2 + 90).

6. If the retailer's inventory position is at or below its reorder point, the retailer places an order with its wholesaler. Retailers A11 and A12 order from wholesaler A1, retailers A21 and A22 order from wholesaler A2, and so on. These orders are made in writing and delivered to the appropriate wholesaler. No other communication is permitted.

For the wholesalers, the procedure each period is the following:

1. The wholesaler accepts into stock any orders due to arrive during the current period. The beginning inventory plus the arriving order determine how much inventory the location has available to satisfy demand during that period.

2. Next, the wholesalers look at the replenishment orders from the retailers for that period. These data are not shown to other members of the supply chain but are treated as confidential information.

3. Wholesalers fill orders as long as sufficient inventory (calculated in Step 1) is available.

4. Wholesalers calculate their ending inventory level. If sufficient inventory is available, ending inventory is beginning inventory minus that period's actual demand. If there is not sufficient inventory, then back orders occur. When a back order occurs, your ending inventory value is negative.

5. Wholesalers calculate their inventory position. Inventory position is the ending inventory plus any quantity already ordered that has not yet arrived.

6. If the wholesaler's inventory position is at or below its reorder point, the wholesaler places an order with its distributor. Wholesalers A1 and A2 order from distributor A, wholesalers B1 and B2 order from distributor B, and so on. These orders are in writing and delivered to the appropriate distributor. No other communication is permitted.

For the distributors, the procedure followed each period is the following:

1. The distributor accepts into stock any orders due to arrive during the current period. The beginning inventory plus the arriving order determine how much inventory the location has available to satisfy demand during that period.

2. Next, the distributor looks at the replenishment orders from its wholesalers for that period. These data are not shown to other members of the supply chain but are treated as confidential information.

3. Distributors fill orders as long as sufficient inventory (calculated in Step 1) is available.

4. Distributors calculate their ending inventory level. If sufficient inventory is available, ending inventory is beginning inventory minus that period's actual demand. If there is not sufficient inventory then back orders occur.

5. Distributors calculate their inventory position. Inventory position is the ending inventory plus any quantity already ordered that has not yet arrived.

6. If the distributor's inventory position is at or below its reorder point, the distributor places an order with the factory. These orders are in writing and delivered to the appropriate distributor. No other communication is permitted.

The factory follows these procedures each period:

1. The factory accepts into stock any manufacturing orders completed for the current period. The beginning inventory plus the arriving order determine how much inventory the location has available to satisfy demand during that period.

2. Next, the factory looks at the replenishment orders from the distributors for that period.

3. The factory fills orders as long as sufficient inventory (calculated in Step 1) is available.

4. The factory calculates its ending inventory level. If sufficient inventory is available, ending inventory is beginning inventory minus that period's actual demand. If there is not sufficient inventory, then back orders occur. When a back order occurs, your ending inventory value is negative.

5. The factory calculates its inventory position. Inventory position is the ending inventory plus any quantity already ordered that has not yet arrived.

6. If the factory's inventory position is at or below its reorder point, the factory releases an order to manufacturing.

Procedures for all locations include the following:

1. At the end of each period, record the amount of actual inventory you have left, the actual number of back orders, the cost of holding the inventory, the cost of the back orders, and the total cost.

2. Update your total statistics, that is, keep a running total of the cases of inventory, the number of back orders, and the cumulative holding costs, cumulative back order costs, and total costs.

End of Game Discussion Questions

1. How well does the distribution system seem to work? Talk about it in terms of customer service, costs, effective use of inventory, and information flows.

2. Given the amount of inventory in the system, why did back orders occur?

3. In this distribution chain, what happened to customer demand data?

4. How should customer demand data be communicated through the system?

5. What would you recommend be done differently?

CASE: Supply Chain Management at Durham International Manufacturing Company (DIMCO)

Lucille Jenkins, the CEO for the Durham International Manufacturing Company (DIMCO), believes that the company can significantly increase its operating profit by implementing supply chain management. DIMCO manufactures a variety of consumer electronic products, from hair dryers to humidifiers to massagers, for the world market.

Lucille believes that DIMCO has already integrated its internal processes and is ready to proceed with external integration. However, she is uncertain as to which direction to take. Should the company work on integrating the suppliers or the distributors first? Currently, DIMCO uses approximately 1350 different components and/or raw materials in manufacturing its product line. Those components and raw materials are purchased from approximately 375 different suppliers around the world. In terms of distribution, DIMCO currently sends its finished products to a central warehouse that supplies 10 regional distribution centers (RDC); 6 are domestic and 4 are located outside of the United States. Each RDC supplies an average of 12 local distributors that each supply an average of 35 retailers.

Lucille is looking for some advice.

1. Briefly describe DIMCO's supply chain.
2. What are the advantages that DIMCO can gain by implementing supply chain management?
3. What would you recommend DIMCO attempt next? Should it work on integrating the suppliers or the distributors first? Or should it work on both simultaneously?
4. What are your recommendations with regard to the external suppliers?
5 What are your recommendations with regard to the external distributors?

INTERACTIVE CASE Virtual Company

www.wiley.com/college/reid

On-line Case: Cruise International, Inc.

Assignment: *Supply Chain Management at Cruise International, Inc.* Bob Bristol, your boss at CII, just called to tell you that he was impressed with your progress thus far in familiarizing yourself with operations at CII—both the strategic details pertaining to its mission, competitive priorities, and so on, and the specific details concerning its services and processes. He tells you that with all the buzz about supply chain management (SCM) that you hear these days, CII is actively interested in exploring how different SCM concepts and techniques could be used in their operations. Providing an adequate, assured supply of a variety of mechanical equipment, entertainment equipment, retail merchandise, food products, and supplies for maintaining the ship is critical to CII. Meghan Willoughby, Chief Purser aboard the *Friendly Seas I*, has a couple of specific assignments that you will work on later. But for now, Meghan would like a concise research report for the top management team addressing SCM issues relevant to CII. This assignment will enhance your knowledge of the material in Chapter 4 of your textbook while preparing you for future assignments.

To access the Web site:

- Go to **www.wiley.com/college/reid**
- Click **Student Companion Site**
- Click **Virtual Company**
- Click **Consulting Assignments**
- Click **Supply Chain Management at CII**

INTERNET CHALLENGE Global Shopping

Since the Internet provides access to products around the world, your challenge involves some global shopping. This year you have been given a budget of $10,000 to furnish and decorate your off-campus apartment. You have chosen a global theme. Your job is to find items from as many different parts of the world as you can to use in your apartment. You can spend up to $10,000 but you cannot exceed your budget. Do not forget that shipping must be included in your budget. You can choose more than a single item from any country.

(a) Visit the Internet to find products for your apartment. You need to furnish a one-bedroom apartment. You do not need to worry about major appliances (computer, television, stereo, oven, refrigerator, dishwasher, etc.), but you do need everything else. Since you plan to host a major party in your new apartment, everything you buy must be delivered within six weeks.

(b) Provide a list of all of the items you would buy, the cost of each item, and the total money spent. Organize your list by the room the item is intended for. Be sure to identify the country of origin for each item. Have fun shopping!

On-line Resources

WILEY PLUS

Companion Website www.wiley.com/college/reid

- Take interactive *practice quizzes* to assess your knowledge and help you study in a dynamic way
- Review *PowerPoint slides* or print slides for notetaking
- Access the *Virtual Company: Cruise International, Inc.*
- Find links to *Company Tours* for this chapter
  Broad Run Cheese House, Curtains & Lace
  BMW Manufacturing Corporation
  Toyota Motor Corporation
- Find links for *Additional Web Resources* for this chapter
  Nummi (New United Motor Manufacturing, Inc.), *www.nummi.org*
  IBM, *www.ibm.com/us*
  Institute for Supply Management, *www.ISM.ws*
  www.manufacturingiscool.com

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CHAPTER 8

Forecasting

Before studying this chapter you should know or, if necessary, review

The role of forecasting in operations management decisions, Chapter 1, p. 8.

LEARNING OBJECTIVES

After studying this chapter you should be able to

1. Identify principles of forecasting.
2. Explain the steps involved in the forecasting process.
3. Identify types of forecasting methods and their characteristics.
4. Describe time series models and causal models.
5. Generate forecasts for data with different patterns, such as level, trend, and seasonality and cycles.
6. Describe causal modeling using linear regression.
7. Compute forecast accuracy.
8. Explain the factors that should be considered when selecting a forecasting model.

CHAPTER OUTLINE

WHAT'S IN OM FOR ME?

ACC FIN MKT OM HRM MIS

Have you ever gone to a restaurant and been told that they are sold out of their "specials," or gone to the university bookstore and found that the texts for your course are on backorder? Have you ever had a party at your home only to realize that you don't have enough food for everyone invited? Just like getting caught unprepared in the rain, these situations show the consequences of poor forecasting. Planning for any event requires a forecast of the future. Whether in business or in our own lives, we make forecasts of future events. Based on those forecasts, we make plans and take action.

Patti McConville/The Image Bank/Getty Images

Forecasting is one of the most important business functions because all other business decisions are based on a forecast of the future. Decisions such as which markets to pursue, which products to produce, how much inventory to carry, and how many people to hire all require a forecast. Poor forecasting results in incorrect business decisions and leaves the company unprepared to meet future demands. The consequences can be very costly in terms of lost sales and can even force a company out of business.

▶ **Forecasting**
Predicting future events.

Forecasts are so important that companies are investing billions of dollars in technologies that can help them better plan for the future. For example, the ice-cream giant Ben & Jerry's has invested in business intelligence software that tracks the life of each pint of ice cream, from ingredients to sale. Each pint is stamped with a tracking number that is stored in an Oracle database. Then the company uses the information to track trends, problems, and new business opportunities. They can track such things as seeing if the ice-cream flavor Chocolate Chip Cookie Dough is gaining on Cherry Garcia for the top sales spot, product sales by location, and rates of change. This information is then used to more accurately forecast product sales. Numerous other companies, such as Procter & Gamble, General Electric, Lands' End, Sears, and Red Robin Gourmet Burgers, are investing in the same type of software in order to improve forecast accuracy.

In this chapter you will learn about forecasting, the different types of forecasting methods available, and how to select and use the proper techniques. You will also learn about the latest available software that can help managers analyze and process data to generate forecasts.

PRINCIPLES OF FORECASTING

There are many types of forecasting models. They differ in their degree of complexity, the amount of data they use, and the way they generate the forecast. However, some features are common to all forecasting models. They include the following:

1. *Forecasts are rarely perfect.* Forecasting the future involves uncertainty. Therefore, it is almost impossible to make a perfect prediction. Forecasters know that

they have to live with a certain amount of error, which is the difference between what is forecast and what actually happens. The goal of forecasting is to generate good forecasts *on the average* over time and to keep forecast errors as low as possible.

2. *Forecasts are more accurate for groups or families of items rather than for individual items.* When items are grouped together, their individual high and low values can cancel each other out. The data for a group of items can be stable even when individual items in the group are very unstable. Consequently, one can obtain a higher degree of accuracy when forecasting for a group of items rather than for individual items. For example, you cannot expect the same degree of accuracy if you are forecasting sales of long-sleeved hunter green polo shirts that you can expect when forecasting sales of all polo shirts.
3. *Forecasts are more accurate for shorter than longer time horizons.* The shorter the time horizon of the forecast, the lower the degree of uncertainty. Data do not change very much in the short run. As the time horizon increases, however, there is a much greater likelihood that changes in established patterns and relationships will occur. Because of that, forecasters cannot expect the same degree of forecast accuracy for a long-range forecast as for a short-range forecast. For example, it is much harder to predict sales of a product two years from now than to predict sales two weeks from now.

STEPS IN THE FORECASTING PROCESS

Regardless of what forecasting method is used, there are some basic steps that should be followed when making a forecast:

1. *Decide what to forecast.* Remember that forecasts are made in order to plan for the future. To do so, we have to decide what forecasts are actually needed. This is not as simple as it sounds. For example, do we need to forecast sales or demand? These are two different things, and sales do not necessarily equal the total amount of demand for the product. Both pieces of information are usually valuable.

   An important part of this decision is the level of detail required for the forecast (e.g., by product or product group), the units of the forecast (e.g., product units, boxes, or dollars), and the time horizon (e.g., monthly or quarterly).
2. *Evaluate and analyze appropriate data.* This step involves identifying what data are needed and what data are available. This will have a big impact on the selection of a forecasting model. For example, if you are predicting sales for a new product, you may not have historical sales information, which would limit your use of forecasting models that require quantitative data.

   We will also see in this chapter that different types of patterns can be observed in the data. It is important to identify these patterns in order to select the correct forecasting model. For example, if a company was experiencing a high increase in product sales for the past year, it would be important to identify this growth in order to forecast correctly.
3. *Select and test the forecasting model.* Once the data have been evaluated, the next step is to select an appropriate forecasting model. As we will see, there are many models to choose from. Usually we consider factors like *cost* and *ease of use* in selecting a model. Another very important factor is *accuracy*. A common proce-

dure is to narrow the choices to two or three different models and then test them on historical data to see which one is most accurate.

4. *Generate the forecast.* Once we have selected a model, we use it to generate the forecast. But we are not finished, as you will see in the next step.
5. *Monitor forecast accuracy.* Forecasting is an ongoing process. After we have made a forecast, we should record what actually happened. We can then use that information to monitor our forecast accuracy. This process should be carried out continuously because environments and conditions often change. What was a good forecasting model in the past might not provide good results for the future. We have to constantly be prepared to revise our forecasting model as our data change.

LINKS TO PRACTICE

Intel Corporation
www.intel.com

AFP/Getty Images, Inc.

The rapid growth of information technology (IT) has created a forecasting challenge for manufacturers of industry components such as microchips and semiconductors. Companies like Intel have had difficulty in forecasting demand for information technology used in internal applications. Forecasts are critical in order to plan production and have enough product to meet demand. However, overforecasting means having too much of an expensive product that will quickly become obsolete. The exponential growth in requirements and a short product life cycle have added much uncertainty to the forecasting process. Intel has had to consider many factors when generating its forecasts, such as key technology trends that are driving the information revolution and future directions in the use of IT.

TYPES OF FORECASTING METHODS

Forecasting methods can be classified into two groups: *qualitative* and *quantitative.* Table 8-1 shows these two categories and their characteristics.

Qualitative forecasting methods, often called judgmental methods, are methods in which the forecast is made subjectively by the forecaster. They are educated guesses by

▶ **Qualitative forecasting methods**
Forecast is made subjectively by the forecaster.

TABLE 8-1

Types of Forecasting Methods

	Qualitative Methods	Quantitative Methods
1. Characteristics	Based on human judgment, opinions; subjective and nonmathematical.	Based on mathematics; quantitative in nature.
2. Strengths	Can incorporate latest changes in the environment and "inside information."	Consistent and objective; able to consider much information and data at one time.
3. Weaknesses	Can bias the forecast and reduce forecast accuracy.	Often quantifiable data are not available. Only as good as the data on which they are based.

forecasters or experts based on intuition, knowledge, and experience. When you decide, based on your intuition, that a particular team is going to win a baseball game, you are making a qualitative forecast. Because qualitative methods are made by people, they are often biased. These biases can be related to personal motivation ("They are going to set my budget based on my forecast, so I'd better predict high."), mood ("I feel lucky today!"), or conviction ("That pitcher can strike anybody out!").

Quantitative forecasting methods
Forecast is based on mathematical modeling.

Quantitative forecasting methods, on the other hand, are based on mathematical modeling. Because they are mathematical, these methods are consistent. The same model will generate the exact same forecast from the same set of data every time. These methods are also objective. They do not suffer from the biases found in qualitative forecasting. Finally, these methods can consider a lot of information at one time. Because people have limited information-processing abilities and can easily experience information overload, they cannot compete with mathematically generated forecasts in this area.

Both qualitative and quantitative forecasting methods have strengths and weaknesses. Although quantitative methods are objective and consistent, they require data in quantifiable form in order to generate a forecast. Often, we do not have such data, for example, if we are making a strategic forecast or if we are forecasting sales of a new product. Also, quantitative methods are only as good as the data on which they are based. Qualitative methods, on the other hand, have the advantage of being able to incorporate last-minute "inside information" in the forecast, such as an advertising campaign by a competitor, a snowstorm delaying a shipment, or a heat wave increasing sales of ice cream. Each method has its place, and a good forecaster learns to rely on both.

LINKS TO PRACTICE

Improving Sales Forecasting

Reuters New Media Inc./
Corbis Images

Inaccurate forecasts can cost companies billions of dollars in missed sales or excess inventory. One factor that can significantly impact sales is the weather. In the past, there was little companies could do to plan for weather problems. However, new businesses have sprung up to help companies use weather data to predict consumer behavior and manage weather risk. It could be as simple as predicting a hot summer, a cold winter, or an early spring. This type of information can help companies move the right inventories to areas where consumers will be more likely to buy them.

Planalytics Inc. is a company that helps businesses use weather data to make their business plans. Its clients include Gillette's Duracell® Batteries, Home Depot, and Wal-Mart. In one example, Planalytics helped Duracell move a large number of batteries to areas expecting to be hit by hurricanes during the hurricane season. Although using weather data does not replace traditional forecasting methods, it is one additional tool that can help companies improve their forecasting and planning.

Qualitative Methods

There are many types of qualitative forecasting methods, some informal and some structured. Regardless of how structured the process is, however, remember that these models are based on subjective opinion and are not mathematical in nature. Some common qualitative methods are shown in Table 8-2 and are described in this section.

TABLE 8-2

Qualitative Forecasting Methods

Type	Characteristics	Strengths	Weaknesses
Executive opinion	A group of managers meet and come up with a forecast.	Good for strategic or new-product forecasting.	One person's opinion can dominate the forecast.
Market research	Uses surveys and interviews to identify customer preferences.	Good determinant of customer preferences.	It can be difficult to develop a good questionnaire.
Delphi method	Seeks to develop a consensus among a group of experts.	Excellent for forecasting long-term product demand, technological changes, and scientific advances.	Time-consuming to develop.

MKT

Executive Opinion **Executive opinion** is a forecasting method in which a group of managers meet and collectively develop a forecast. This method is often used for strategic forecasting or forecasting the success of a new product or service. Sometimes it can be used to change an existing forecast to account for unusual events, such as an unusual business cycle or unexpected competition.

► **Executive opinion** Forecasting method in which a group of managers collectively develop a forecast.

Although managers can bring good insights to the forecast, this method has a number of disadvantages. Often the opinion of one person can dominate the forecast if that person has more power than the other members of the group or is very domineering. Think about times when you were part of a group for a course or for your job. Chances are that you experienced situations in which one person's views dominated.

Market Research **Market research** is an approach that uses surveys and interviews to determine customer likes, dislikes, and preferences and to identify new-product ideas. Usually, the company hires an outside marketing firm to conduct a market research study. There is a good chance that you were a participant in such a study if someone called you and asked about your product preferences.

► **Market research** Approach to forecasting that relies on surveys and interviews to determine customer preferences.

Market research can be a good determinant of customer preferences. However, it has a number of shortcomings. One of the most common has to do with how the survey questions are designed. For example, a market research firm may call and ask you to identify which of the following is your favorite hobby: gardening, working on cars, cooking, or playing sports. But maybe none of these is your favorite because you prefer playing the piano or fishing, and these options are not included. This question is poorly designed because it forces you to pick a category that you really don't fit in, which can lead to misinterpretation of the survey results.

MKT

The Delphi Method The **Delphi method** is a forecasting method in which the objective is to reach a consensus among a group of experts while maintaining their anonymity. The researcher puts together a panel of experts in the chosen field. These experts do not have to be in the same facility or even in the same country. They do not know who the other panelists are. The process involves sending questionnaires to the panelists, then summarizing the findings and sending them an updated questionnaire incorporating the findings. This process continues until a consensus is reached.

► **Delphi method** Approach to forecasting in which a forecast is the product of a consensus among a group of experts.

The idea behind the Delphi method is that a panel of experts in a particular field might not agree on certain things, but what they do agree on will probably happen.

Dennis MacDonald/PhotoEdit

Market research being conducted in a shopping mall.

Jean Louis Batt/Taxi/Getty Images, Inc.

Computers have made the use of quantitative models much easier.

The researcher's job is to identify what the experts agree on and use that as the forecast. This method has the advantage of not allowing anyone to dominate the consensus, and it has been shown to work very well. Although it takes a large amount of time, it has been shown to be an excellent method for forecasting long-range product demand, technological change, and scientific advances in medicine. For example, if you wished to predict the timing for an AIDS vaccine or a cure for cancer, you would probably use this technique.

Quantitative Methods

Quantitative methods are different from qualitative ones because they are based on mathematics. Quantitative methods can also be divided into two categories: *time series models* and *causal models*. Although both are mathematical, the two categories differ in their assumptions and in the manner in which a forecast is generated. In this section we will study some common quantitative models, which are summarized in Table 8-3.

▶ **Time series models**
Based on the assumption that a forecast can be generated from the information contained in a time series of data.

▶ **Time series**
A series of observations taken over time.

▶ **Causal models**
Based on the assumption that the variable being forecast is related to other variables in the environment.

Time series models assume that all the information needed to generate a forecast is contained in the *time series* of data. A **time series** is a series of observations taken at regular intervals over a specified period of time. For example, if you were forecasting quarterly corporate sales and had collected five years of quarterly sales data, you would have a time series. Time series analysis assumes that we can generate a forecast based on patterns in the data. As a forecaster, you would look for patterns such as trend, seasonality, and cycle and use that information to generate a forecast.

Causal models, sometimes called associative models, use a very different logic to generate a forecast. They assume that the variable we wish to forecast is somehow related to other variables in the environment. The forecaster's job is to discover how these variables are related in mathematical terms and use that information to forecast

the future. For example, we might decide that sales are related to advertising dollars and GNP. From historical data we would build a model that explains the relationship of these variables and use it to forecast corporate sales.

Time series models are generally easier to use than causal models. Causal models can be very complex, especially if they consider relationships among many variables. However, time series models can often be just as accurate and have the advantage of simplicity. They are easy to use and can generate a forecast more quickly than causal models, which require model building. Each of these models is used for forcasting in operations management and will be described in the next section.

TABLE 8-3

Quantitative Forecasting Models

Type	Description	Strengths	Weaknesses
Time Series Models			
Naïve	Uses last period's actual value as a forecast.	Simple and easy to use.	Only good if data change little from period to period.
Simple Mean	Uses an average of past data as a forecast.	Good for level pattern.	Requires carrying a lot of data.
Simple Moving Average	A forecasting method in which only *n* of the most recent observations are averaged.	Only good for level pattern.	Important to select the proper moving average.
Weighted Moving Average	A forecasting method where *n* of the most recent observations are averaged and past observations may have different weights.	Good for level pattern; allows placing different weights on past demands.	Selection of weights requires good judgment.
Exponential Smoothing	A weighted average procedure with weights declining exponentially as data become older.	Provides excellent forecast results for short- to medium-length forecasts.	Choice of alpha is critical.
Trend-Adjusted Exponential Smoothing	An exponential smoothing model with separate equations for forecasting the level and trend.	Provides good results for trend data.	Should only be used for data with trend.
Linear Trend Line	Technique uses the least-squares method to fit a straight line to past data over time.	Easy to use and understand.	Data should display a clear trend over time.
Seasonal Indexes	Computes the percentage amount by which data for each season are above or below the mean.	Simple and logical procedure for computing seasonality.	Make sure seasonality is actually present.
Causal (Associative) Models			
Linear Regression	Uses the least-squares method to model a linear relationship between two variables.	Easy to understand; provides good forecast accuracy.	Make sure a linear relationship is present.
Multiple Regression	Similar to linear regression, but models the relationship of multiple variables with the variable being forecast.	A powerful tool in forecasting when multiple variables are being considered.	Significantly increases data and computational requirements.

TIME SERIES MODELS

Remember that time series analysis assumes that all the information needed to generate a forecast is contained in the time series of the data. The forecaster looks for patterns in the data and tries to obtain a forecast by projecting that pattern into the future. The easiest way to identify patterns is to plot the data and examine the resulting graphs. If we did that, what could we observe? There are four basic patterns, which are shown in Figure 8-1. Any of these patterns, or a combination of them, can be present in a time series of data:

▶ **Level or horizontal pattern**
Pattern in which data values fluctuate around a constant mean.

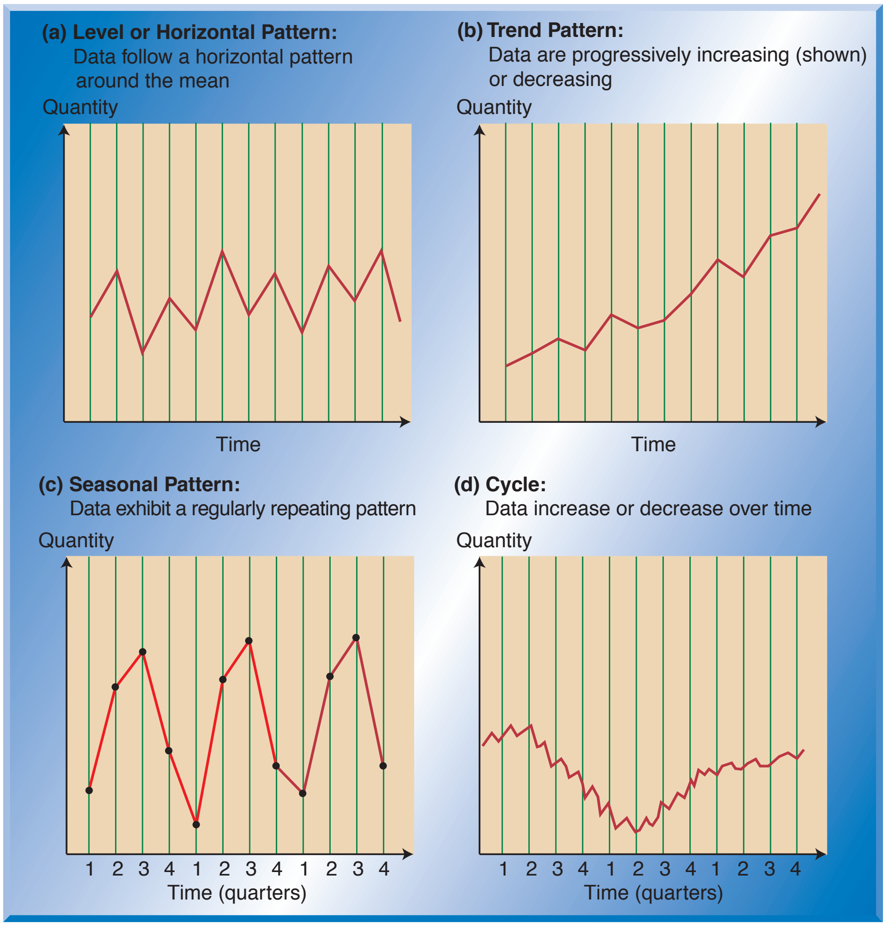
▶ **Trend**
Pattern in which data exhibit increasing or decreasing values over time.

▶ **Seasonality**
Any pattern that regularly repeats itself and is constant in length.

1. *Level or horizontal.* A **level or horizontal pattern** exists when data values fluctuate around a constant mean. This is the simplest pattern and the easiest to predict. An example is sales of a product that do not increase or decrease over time. This type of pattern is common for products in the mature stage of their life cycle, in which demand is steady and predictable.
2. *Trend.* When data exhibit an increasing or decreasing pattern over time, we say that they exhibit a **trend**. The trend can be upward or downward. The simplest type of trend is a straight line, or linear trend.
3. *Seasonality.* A seasonal pattern is any pattern that regularly repeats itself and is of a constant length. Such **seasonality** exists when the variable we are trying to forecast is influenced by seasonal factors such as the quarter or month of the year or day of

FIGURE 8-1

Types of data patterns



the week. Examples are a retail operation with high sales during November and December or a restaurant with peak sales on Fridays and Saturdays.

4. *Cycles.* Patterns that are created by economic fluctuations such as those associated with the business cycle are called **cycles**. These could be recessions, inflation, or even the life cycle of a product. The major distinction between a seasonal pattern and a cyclical pattern is that a cyclical pattern varies in length and magnitude and therefore is much more difficult to forecast than other patterns.

▶ **Cycles**
Data patterns created by economic fluctuations.

Random variation is unexplained variation that cannot be predicted. So if we look at any time series, we can see that it is composed of the following:

▶ **Random variation**
Unexplained variation that cannot be predicted.

$$\text{Data} = \underbrace{\text{level} + \text{trend} + \text{seasonality} + \text{cycles}}_{\text{pattern}} + \text{random variation}$$

$$\text{Data} = \text{pattern} + \text{random variation}$$

The first four components of the data are part of a pattern that we try to forecast. Random variation cannot be predicted. Some data have a lot of random variation and some have little. The more random variation a data set has, the harder it is to forecast accurately. As we will see, many forecasting models try to eliminate as much of the random variation as possible.

Forecasting Level or Horizontal Pattern

The simplest pattern is the level or horizontal pattern. In this section we look at some forecasting models that can be used to forecast the level of a time series.

The Naïve Method The **naïve method** is one of the simplest forecasting models. It assumes that the next period's forecast is equal to the current period's actual. For example, if your sales were 500 units in January, the naïve method would forecast 500 units for February. It is assumed that there is little change from period to period. Mathematically, we could put this in the following form:

▶ **Naïve method**
Forecasting method that assumes next period's forecast is equal to the current period's actual value.

$$F_{t+1} = A_t$$

where F_{t+1} = forecast for next period, $t + 1$
A_t = actual value for current period, t
t = current time period

EXAMPLE 8.1

Forecasting with the Naïve Method

A restaurant is forecasting sales of chicken dinners for the month of April. Total sales of chicken dinners for March were 320. If management uses the naïve method to forecast, what is their forecast of chicken dinners for the month of April?

• **Before You Begin:** Remember that with the naïve method the forecast for next period (April) is equal to the current period's actual value, which is 320 dinners for the month of March.

• **Solution:**
Our equation is

$$F_{t+1} = A_t$$

Adding the appropriate time period:

$$F_{\text{April}} = A_{\text{March}}$$

$$F_{\text{April}} = 320 \text{ dinners}$$

The naïve method can be modified to take trend into account. If we see that our trend is increasing by 10 percent and the current period's sales are 100 units, a naïve method with trend would give us current period's sales plus 10 percent, which is a forecast of 110 units for the next period. The naïve method can also be used for seasonal data. For example, suppose that we have monthly seasonality and know that sales for last January were 230 units. Using the naïve method, we would forecast sales of 230 units for next January.

One advantage of the naïve method is that it is very simple. It works well when there is little variation from one period to the next. Most of the time we use this method to evaluate the forecast performance of other, more complicated forecasting models. Because the naïve method is simple and effortless, we expect the forecasting model that we are using to perform better than naïve.

▶ **Simple mean or average**
The average of a set of data.

Simple Mean or Average

One of the simplest averaging models is the **simple mean or average**. Here the forecast is made by simply taking an average of all data:

$$F_{t+1} = \frac{\Sigma A_t}{n} = \frac{A_t + A_{t-1} + \cdots + A_{t-n}}{n}$$

where F_{t+1} = forecast of demand for next period, $t + 1$
A_t = actual value for current period, t
n = number of periods or data points to be averaged

EXAMPLE 8.2

Forecasting with the Mean

New Tools Corporation is forecasting sales for its classic product, Handy-Wrench. Handy-Wrench sales have been steady, and the company uses a simple mean to forecast. Weekly sales over the past five weeks are available. Use the mean to make a forecast for week 6.

Time Period (in weeks)	Actual Sales	Forecast
1	51	
2	53	
3	48	
4	52	
5	50	
6	—	50.8

• **Before You Begin:** Remember that using the mean requires the averaging of all the available data.

• **Solution:**
The basic equation for the mean is

$$F_{t+1} = \frac{\Sigma A_t}{n}$$

$$F_6 = \frac{51 + 53 + 48 + 52 + 50}{5}$$

$$F_6 = 50.8$$

This model is only good for a level data pattern. As the average becomes based on a larger and larger data set, the random variation and the forecasts become more stable. One of the advantages of this model is that only two historical pieces of information need to be carried: the mean itself and the number of observations on which the mean was based.

Simple Moving Average The **simple moving average (SMA)** is similar to the simple average except that we are not taking an average of all the data, but are including only n of the most recent periods in the average. As new data become available, the oldest are dropped; the number of observations used to compute the average is kept constant. In this manner, the simple moving average "moves" through time. Like the simple mean, this model is good only for forecasting level data. The formula is as follows:

Simple moving average (SMA) A forecasting method in which only n of the most recent observations are averaged.

$$F_{t+1} = \frac{\Sigma A_t}{n} = \frac{A_t + A_{t-1} + \cdots + A_{t-n}}{n}$$

where F_{t+1} = forecast of demand for the next period, $t + 1$
A_t = actual value for current period, t
n = number of periods or data points used in the moving average

The formula for the moving average is the same as that for the simple average, except that we use only a small portion of the data to compute the average. For example, if we used a moving average of $n = 3$, we would be averaging only the latest three periods. If we were using a moving average of $n = 5$, we would be averaging only the latest five periods.

EXAMPLE 8.3 Forecasting with the Simple Moving Average (Three-Period MA)

Sales forecasts for a product are made using a three-period moving average. Given the following sales figures for January, February, and March, make a forecast for April.

Month	Actual Sales
January	200
February	300
March	200

• **Before You Begin:** Remember that to use a three-period moving average, you have to compute the average of the latest three observations. As new data become available, you drop off the oldest data, always averaging the latest three observations.

• **Solution:**

To find the forecast for April, we take an average of the last three observations:

$$F_{t+1} = \frac{\Sigma A_t}{n}$$

$$F_{\text{April}} = \frac{A_{\text{January}} + A_{\text{February}} + A_{\text{March}}}{3} = \frac{200 + 300 + 200}{3} = 233.3$$

If the actual sales for April turn out to be 300, let's make a forecast for May. Using a three-period moving average, we take an average of the latest three observations. Since we are now able to include actual sales for April, we drop the sales for January:

$$F_{\text{May}} = \frac{A_{\text{February}} + A_{\text{March}} + A_{\text{April}}}{3} = \frac{300 + 200 + 300}{3} = 266.9$$

Similarly, if the actual sales for May turn out to be 400, we can make a forecast for June:

$$F_{\text{June}} = \frac{A_{\text{March}} + A_{\text{April}} + A_{\text{May}}}{3} = \frac{200 + 300 + 400}{3} = 300.0$$

Then, if the actual sales for June turn out to be 500, the forecast for July is computed as

$$F_{\text{July}} = \frac{A_{\text{April}} + A_{\text{May}} + A_{\text{June}}}{3} = \frac{300 + 400 + 500}{3} = 400.0$$

The other forecasts follow in a similar fashion. If actual sales for July and August turn out to be 600 and 650, respectively, then the respective forecasts for August and September are

$$F_{\text{August}} = \frac{A_{\text{May}} + A_{\text{June}} + A_{\text{July}}}{3} = \frac{400 + 500 + 600}{3} = 500.0$$

$$F_{\text{September}} = \frac{A_{\text{June}} + A_{\text{July}} + A_{\text{August}}}{3} = \frac{500 + 600 + 650}{3} = 583.3$$

Here is a summary of the forecasts we have made and the actual sales values:

Month	Actual Sales	Forecast Three-Period Moving Average
January	200	—
February	300	—
March	200	—
April	300	233.3
May	400	266.9
June	500	300.0
July	600	400.0
August	650	500.0
September	—	583.3

Just like the mean, the moving average is good only for a level pattern. You can see this in Example 8.3. The data shown in the example are level in the first four periods. However, after the fourth period the data begin to show a trend. You can see that the forecasts made with the moving average also begin to show an upward trend. Do you see a problem with the forecasts?

The problem is that the forecasts are trailing behind the actual data. We say that they are "lagging" the data. This is what happens when you apply a model that is good only for a level pattern to data that have a trend. You will not obtain a good forecast.

EXAMPLE 8.4

Forecasts with the Simple Moving Average (Five-Period MA)

Using data from Example 8.3, make forecasts for the months of June, July, August, and September using a five-period moving average.

- **Before You Begin:** In this problem we are going to compute the average of the last five available observations. As we move through time and new data become available, we will drop the oldest data and add the most recent, always averaging the latest five observations.

- **Solution:**
Notice that we are now going to average the last five available observations. Using a five-period moving average, the forecasts for June, July, August, and September are computed as follows:

$$F_{\text{June}} = \frac{A_{\text{January}} + A_{\text{February}} + A_{\text{March}} + A_{\text{April}} + A_{\text{May}}}{5} = \frac{200 + 300 + 200 + 300 + 400}{5}$$

$$F_{\text{June}} = 280$$

$$F_{\text{July}} = \frac{A_{\text{February}} + A_{\text{March}} + A_{\text{April}} + A_{\text{May}} + A_{\text{June}}}{5} = \frac{300 + 200 + 300 + 400 + 500}{5}$$

$$F_{\text{July}} = 340$$

$$F_{\text{August}} = \frac{A_{\text{March}} + A_{\text{April}} + A_{\text{May}} + A_{\text{June}} + A_{\text{July}}}{5} = \frac{200 + 300 + 400 + 500 + 600}{5}$$

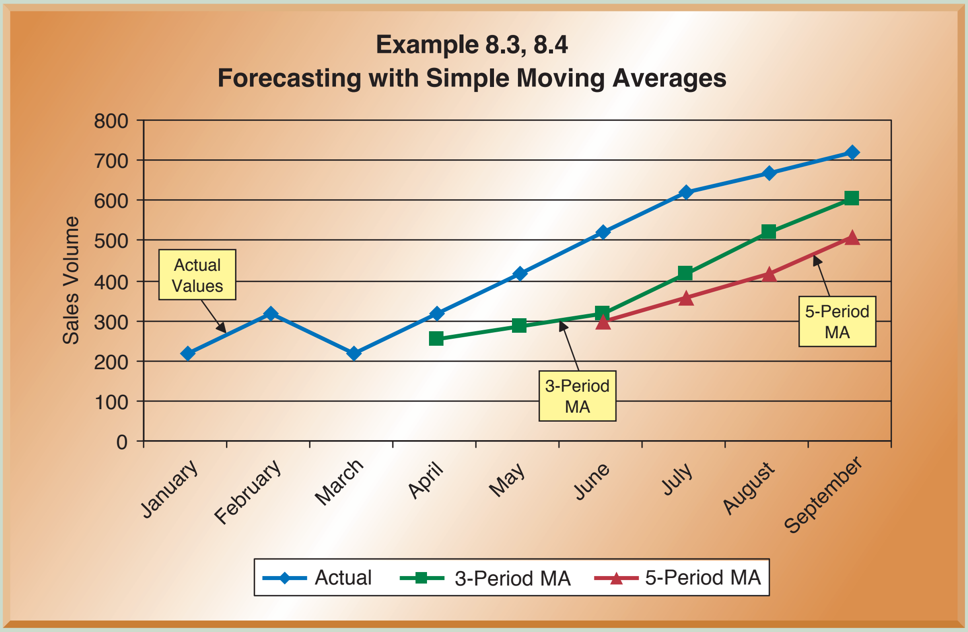
$$F_{\text{August}} = 400$$

$$F_{\text{September}} = \frac{A_{\text{April}} + A_{\text{May}} + A_{\text{June}} + A_{\text{July}} + A_{\text{August}}}{5} = \frac{300 + 400 + 500 + 600 + 650}{5}$$

$$F_{\text{September}} = 490$$

Following is a summary of the forecasts and the actual sales values:

Month	Actual Sales	Forecast Five-Period Moving Average
January	200	
February	300	
March	200	
April	300	
May	400	
June	500	280
July	600	340
August	650	400
September	—	490



Example 8.3, 8.4
Forecasting with Simple Moving Averages

Comparing the three-period and five-period moving average forecasts, we can see that the three-period moving average forecasts are more responsive to the period-to-period changes in the actual data—they follow the data more closely. The reason is that the smaller the number of observations in the moving average, the more *responsive* the forecast is to changes in demand. However, the forecast is also more subject to the random changes in the data. If the data contain a lot of randomness, high responsiveness could lead to greater errors. On the other hand, the larger the number of observations in the moving average, the less responsive the forecast is to changes in the demand, but also to the randomness. These forecasts are more *stable*. One is not better than the other. Selection of the number of observations in the moving average should be based on the characteristics of the data.

Weighted Moving Average In the simple moving average each observation is weighted equally. For example, in a three-period moving average each observation is weighted one-third. In a five-period moving average each observation is weighted one-fifth. Sometimes a manager wants to use a moving average but gives higher or lower weights to some observations based on knowledge of the industry. This is called a **weighted moving average**. In a weighted moving average, each observation can be weighted differently provided that all the weights add up to 1.

▶ **Weighted moving average** A forecasting method in which n of the most recent observations are averaged and past observations may be weighted differently.

$$F_{t+1} = \Sigma C_t A_t = C_1 A_1 + C_2 A_2 + \cdots + C_t A_t$$

where F_{t+1} = next period's forecast
C_t = weight placed on the actual value in period t
A_t = actual value in period t

EXAMPLE 8.5

Forecasting with a Weighted Moving Average

A manager at Fit Well department store wants to forecast sales of swimsuits for August using a three-period weighted moving average. Sales for May, June, and July are as follows:

Month	Actual Sales	Forecast
May	400	
June	500	
July	600	

The manager has decided to weight May (0.25), June (0.25), and July (0.50).

- **Before You Begin:** Remember that to compute a weighted moving average you need to multiply each observation by its corresponding weight. These values are then summed in order to get a weighted average.

- **Solution:**

The forecast for August is computed as follows:

$$F_{t+1} = \Sigma C_t A_t$$

$$F_{\text{August}} = (0.25)A_{\text{May}} + (0.25)A_{\text{June}} + (0.50)A_{\text{July}}$$

$$= (0.25)400 + (0.25)500 + (0.50)600$$

$$= 525$$

Exponential Smoothing The **exponential smoothing model** is a forecasting model that uses a sophisticated weighted average procedure to obtain a forecast. Even though it is sophisticated in the way it works, it is easy to use and understand. To make a forecast for the next time period, you need three pieces of information:

▶ **Exponential smoothing model**
Uses a sophisticated weighted average procedure to generate a forecast.

1. The current period's forecast,
2. The current period's actual value
3. The value of a smoothing coefficient, α, which varies between 0 and 1

The equation for the forecast is quite simple:

Next period's forecast = α (current period's actual) + (1 − α) (current period's forecast)

In mathematical terms:

$$F_{t+1} = \alpha A_t + (1 - \alpha)F_t$$

where F_{t+1} = forecast of demand for next period, $t + 1$
A_t = actual value for current period, t
F_t = forecast for current period, t
α = smoothing coefficient

Exponential smoothing models are the most frequently used forecasting techniques and are available on almost all computerized forecasting software. These models are widely used, particularly in operations management. They have been shown to produce accurate forecasts under many conditions, yet are relatively easy to use and understand.

EXAMPLE 8.6

Forecasting with Exponential Smoothing

The Hot Tamale Mexican restaurant uses exponential smoothing to forecast monthly usage of tabasco sauce. Its forecast for September was 200 bottles, whereas actual usage in September was 300 bottles. If the restaurant's managers use an α of 0.70, what is their forecast for October?

• **Before You Begin:** In this problem you are to use the exponential smoothing equation to get a forecast. You have been given the three pieces of information you need: the current period's forecast (200 bottles), the current period's actual value (300 bottles), and the value for the smoothing coefficient α, 0.70.

• **Solution:**
The general equation for exponential smoothing is

$$\begin{aligned} F_{t+1} &= \alpha A_t + (1 - \alpha)F_t \\ F_{\text{October}} &= \alpha A_{\text{September}} + (1 - \alpha)F_{\text{September}} \\ &= (0.70)(300) + (0.30)200 \\ &= 270 \text{ bottles} \end{aligned}$$

Selecting α Note that depending on which value you select for α, you can place more weight on either the current period's actual or the current period's forecast. In this manner the forecast can depend more heavily either on what happened most recently or on the current period's forecast. Values of α that are low—say, 0.1 or 0.2—generate forecasts that are very stable because the model does not place much weight on the current period's actual demand. Values of α that are high, such as 0.7 or 0.8, place a lot of weight on the current period's actual demand and can be influenced by random variations in the data. Thus, how α is selected is very important in getting a good forecast.

Starting the Forecasting Process with Exponential Smoothing One thing you may notice with exponential smoothing is that you need the current period's actual and current period's forecast to make a forecast for the next period. However, what if you are just starting the forecasting process and do not have a value for the current period's forecast? There are many ways to handle this problem, but the most common is to use the naïve method to generate an initial forecast. Another option is to average the last few periods—say, the last three or four—just to get a starting point.

EXAMPLE 8.7

Comparing Forecasts with Different Values of α

To illustrate the differences between different values of α, let's consider two series of forecasts for a data set. One set of forecasts was developed using exponential smoothing with $\alpha = 0.10$, another with an $\alpha = 0.60$.

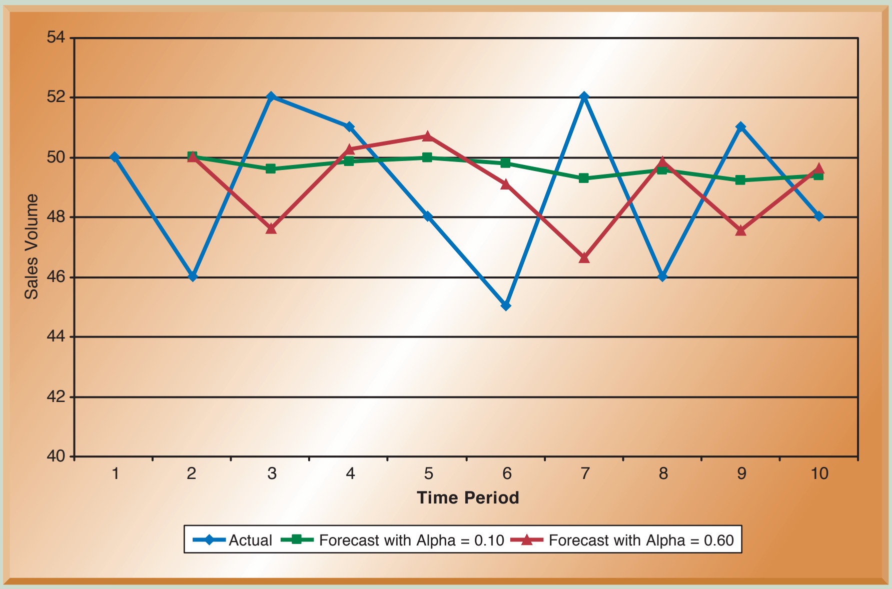
Time Period (t)	Actual Demand	Exponential Smoothing Forecasts $\alpha = 0.10$	Exponential Smoothing Forecasts $\alpha = 0.60$
1	50	—	—
2	46	50	50
3	52	49.60	47.60
4	51	49.84	50.24
5	48	49.96	50.70
6	45	49.77	49.08
7	52	49.29	46.63
8	46	49.56	49.85
9	51	49.20	47.54
10	48	49.38	49.62

- **Before You Begin:** When using the exponential smoothing equation, always make sure you have the three pieces of information needed: the current period's forecast, the current period's actual value, and a value for the smoothing coefficient, α. This problem illustrates how you can begin the exponential smoothing process when you do not have initial forecast values.

- **Solution:**

Notice that we used the naïve method to derive initial values of forecasts for period 2. Then to obtain forecasts for period 3, we used the exponential smoothing equation with different values of α. For an $\alpha = 0.10$, the forecast for period 3 is computed as

$$F_3 = (0.10)(46) + (0.90)(50) = 49.6$$



For an $\alpha = 0.60$, the forecast for period 3 is computed as:

$$F_3 = (0.60)(46) + (0.40)(50) = 47.6$$

The remaining forecasts are computed in the same manner. We can see from the graph that the forecasts with a lower value of α (0.10) have less variation than those with the higher value of α (0.60), indicating that they are more stable.

Before You Go On

We have discussed the principles of forecasting, how to forecast, and different types of qualitative and quantitative forecasting models. We have also learned about different types of patterns present in the data. You should understand that to obtain a good forecast the forecasting model should be matched to the patterns in the available data. Our example of the moving average shows what happens when the data show a trend but the model selected is useful only for forecasting a level pattern.

All the quantitative models discussed so far are meant only for level data patterns. In the next section we turn to quantitative models that can be used for other data patterns, such as trend and seasonality. However, remember that the models already discussed are the foundation of forecasting.

Forecasting Trend

There are many ways to forecast trend patterns in data. Most of the models used for forecasting trend are the same models used to forecast the level patterns, with an additional feature added to compensate for the lagging that would otherwise occur. Here we will look at two of the most common trend models.

Trend-Adjusted Exponential Smoothing **Trend-adjusted exponential smoothing** uses three equations. The first smooths out the level of the series, the second smooths out the trend, and the third generates a forecast by adding up the findings from the first two equations. Because we are using a second exponential smoothing equation to compute trend, we have two smoothing coefficients. In addition to α, which is used to smooth out the level of the series, we have a second coefficient, β, which is used to smooth out the trend of the series. Like α, β can theoretically vary between 0 and 1, though we tend to keep the value conservatively low, around 0.1 or 0.2.

▶ **Trend-adjusted exponential smoothing** Exponential smoothing model that is suited to data that exhibit a trend.

Three steps must be followed to generate a forecast with trend:

Step 1 Smoothing the Level of the Series

$$S_t = \alpha A_t + (1 - \alpha)(S_{t-1} + T_{t-1})$$

Step 2 Smoothing the Trend

$$T_t = \beta(S_t - S_{t-1}) + (1 - \beta)T_{t-1}$$

Step 3 Forecast Including Trend

$$FIT_{t+1} = S_t + T_t$$

where FIT_{t+1} = forecast including trend for next period, $t + 1$
S_t = exponentially smoothed average of the time series in period t
T_t = exponentially smoothed trend of the time series in period t
α = smoothing coefficient of the level
β = smoothing coefficient of the trend

Note that the last step simply adds up the findings from the first two steps. Next we will look at an example of how this works.

EXAMPLE 8.8

Forecasting with Trend-Adjusted Exponential Smoothing

Green Grow is a lawn care company that uses exponential smoothing with trend to forecast monthly usage of its lawn care products. At the end of July the company wishes to forecast sales for August. The trend through June has been 15 additional gallons of product sold per month. Average sales have been 57 gallons per month. The demand for July was 62 gallons. The company uses $\alpha = 0.20$ and $\beta = 0.10$. Make a forecast including trend for the month of August.

- **Before You Begin:** When solving this type of problem, always begin by identifying the information that is given in the problem.

The information we have is

$$S_{\text{June}} = 57 \text{ gallons/month}$$

$$T_{\text{June}} = 15 \text{ gallons/month}$$

$$A_{\text{July}} = 62 \text{ gallons}$$

$$\alpha = 0.20$$

$$\beta = 0.10$$

Next, use the three equations needed to generate a forecast including trend. For each equation we will substitute the appropriate values.

- **Solution:**

Step 1 Smoothing the Level of the Series

$$S_t = \alpha A_t + (1 - \alpha)(S_{t-1} + T_{t-1})$$

$$\begin{aligned} S_{\text{July}} &= \alpha A_{\text{July}} + (1 - \alpha)(S_{\text{June}} + T_{\text{June}}) \\ &= (0.20)(62) + (0.80)(57 + 15) \\ &= 70 \end{aligned}$$

Step 2 Smoothing the Trend

$$T_t = \beta(S_t - S_{t-1}) + (1 - \beta)T_{t-1}$$

$$\begin{aligned} T_{\text{July}} &= \beta(S_{\text{July}} - S_{\text{June}}) + (1 - \beta)T_{\text{June}} \\ &= (0.1)(70 - 57) + (0.90)15 \\ &= 14.8 \end{aligned}$$

Step 3 Forecast Including Trend

$$FIT_{t+1} = S_t + T_t$$

$$\begin{aligned} FIT_{\text{August}} &= S_{\text{July}} + T_{\text{July}} \\ &= 70 + 14.8 \\ & 84.8 \text{ gallons} \end{aligned}$$

Linear Trend Line Linear trend line is a time series technique that computes a forecast with trend by drawing a straight line through a set of data. This approach is a version of the linear regression technique, covered later in this chapter, and is useful for computing a forecast when data display a clear trend over time. The method is simple, easy to use, and easy to understand.

A linear trend line uses the following equation to generate a forecast:

$$Y = a + bX$$

where Y = forecast for period X
X = the number of time periods from $X = 0$
a = value of Y at $X = 0$ (Y intercept)
b = slope of the line

The coefficients a and b are computed using the least-squares method, which minimizes the sum of the squared errors. Developing the equations for a and b can be complicated, so we will only provide the equations needed for computation. The steps for computing the forecast using a linear trend line are as follows:

Step 1 Compute parameter b:

$$b = \frac{\Sigma XY - n\overline{X}\overline{Y}}{\Sigma X^2 - n\overline{X}^2}$$

Step 2 Compute parameter a:

$$a = \overline{Y} - b\overline{X}$$

Step 3 Generate the linear trend line:

$$Y = a + bX$$

Step 4 Generate a forecast (Y) for the appropriate value of time (X)

EXAMPLE 8.9

Forecasting with a Linear Trend Line

A manufacturer has plotted product sales over the past four weeks. Use a linear trend line to generate a forecast for week 5.

- **Before You Begin:** Remember to follow the four steps given in the text for generating a forecast using a linear trend line.

- **Solution:**

	Weeks X	Sales Y	X^2	XY
	1	2,300	1	2,300
	2	2,400	4	4,800
	3	2,300	9	6,900
	4	2,500	16	10,000
Totals	**10**	**9,500**	**30**	**24,000**

$$\overline{Y} = 2375 \qquad \overline{X} = 2.5$$

Step 1 Compute parameter b:

$$b = \frac{\Sigma XY - n\overline{X}\overline{Y}}{\Sigma X^2 - n\overline{X}^2} = \frac{24{,}000 - 4(2.5)(2375)}{30 - 4(2.5)^2} = \frac{250}{5} = 50$$

Step 2 Compute parameter a:

$$a = \overline{Y} - b\overline{X} = 2375 - (50)(2.5) = 2250$$

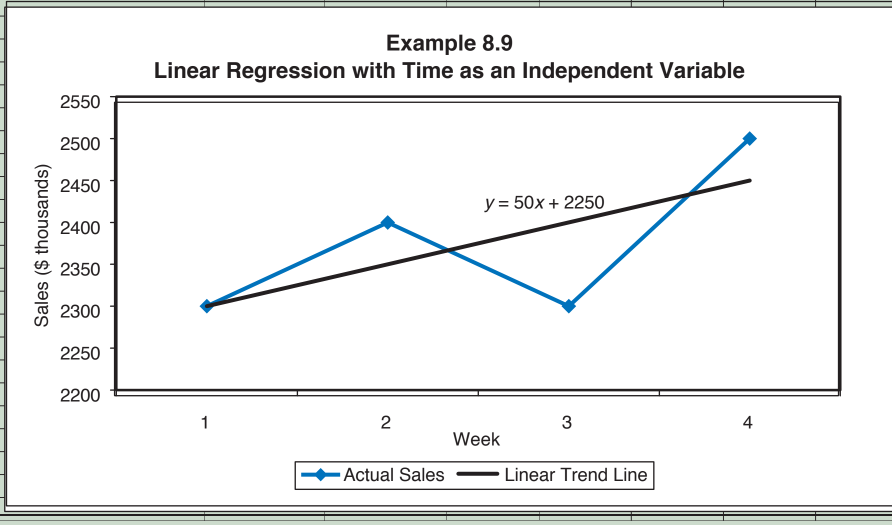
Step 3 Compute the linear trend line:

$$Y = a + bX$$
$$= 2250 + 50X$$

Step 4 For the fifth week, the value of sales would be

$$Y = 2250 + 50(5) = 2500$$

	A	B	C	D	E	F	G	H
4	**Weeks (X)**	**Sales (Y)**						
5	1	2300						
6	2	2400						
7	3	2300						
8	4	2500						
9			B10: =SLOPE(B5:B8,A5:A8)					
10	Slope Coefficient (b)	50.00	B11: =INTERCEPT(B5:B8,A5:A8)					
11	Intercept Coefficient (a)	2250.00						



Forecasting Seasonality

Recall that any regularly repeating pattern is a seasonal pattern. We are all familiar with quarterly and monthly seasonal patterns. Whether your university is on a quarter or semester plan, you can see that enrollment varies between quarters or semesters in a fairly predictable way. For example, enrollment is usually much higher in the fall than in the summer. Other examples of seasonality include sales of turkeys before Thanksgiving or ham before Easter, sales of greeting cards, hotel registrations, and sales of gardening tools.

The amount of seasonality is the extent to which actual values deviate from the average or mean of the data. Here we will consider only *multiplicative seasonality*, in which the seasonality is expressed as a percentage of the average. The percentage by which the value for each season is above or below the mean is a **seasonal index**. For example, if enrollment for the fall semester at your university is 1.30 of the mean, the fall enrollment is 30 percent above the average. Similarly, if enrollment for the summer semester is 0.70 of the mean, then summer enrollment is 70 percent of the average.

▶ **Seasonal index**
Percentage amount by which data for each season are above or below the mean.

Here we will show only the procedure for computing quarterly seasonality that lasts a year, though the same procedure can be used for any other type of seasonality. The procedure consists of the following steps:

Step 1 Calculate the Average Demand for Each Quarter or "Season." This is done by dividing the total annual demand by 4 (the number of seasons per year).

Step 2 Compute a Seasonal Index for Every Season of Every Year for Which You Have Data. This is done by *dividing* the actual demand for each season by the average demand per season (computed in Step 1).

Step 3 Calculate the Average Seasonal Index for Each Season. For each season, compute the average seasonal index by adding up the seasonal index values for that season and dividing by the number of years.

Step 4 Calculate the Average Demand per Season for Next Year. This could be done by using any of the methods used to compute annual demand. Then we would divide that by the number of seasons to determine the average demand per season for next year.

Step 5 Multiply Next Year's Average Seasonal Demand by Each Seasonal Index. This will produce a forecast for each season of next year.

EXAMPLE 8.10

Forecasting Seasonality

U-R-Smart University wants to develop forecasts for next year's quarterly enrollment. It has collected quarterly enrollments for the past two years. It has also forecast total annual enrollment for next year to be 90,000 students. What is the forecast for each quarter of next year?

Enrollment (in thousands)

Quarter	Year 1	Year 2
Fall	24	26
Winter	23	22
Spring	19	19
Summer	14	17
Total	**80**	**84**

• **Before You Begin:** You can see that the data exhibit a seasonal pattern, with each quarter representing a "season." To compute the forecast for each quarter of next year, follow the five steps given in the text on forecasting with seasonality.

• **Solution:**

Step 1 Calculate the Average Demand for Each Quarter or "Season." We do this by dividing the total annual demand for each year by 4:

$$\text{Year 1: } 80/4 = 20$$

$$\text{Year 2: } 84/4 = 21$$

Step 2 Compute a Seasonal Index for Every Season of Every Year for Which You Have Data. To do this we divide the actual demand for each season by the average demand per season.

Enrollment (in thousands)

Quarter	Year 1	Year 2
Fall	24/20 = 1.20	26/21 = 1.238
Winter	23/20 = 1.15	22/21 = 1.048
Spring	19/20 = 0.95	19/21 = 0.905
Summer	14/20 = 0.70	17/21 = 0.810

Step 3 Calculate the Average Seasonal Index for Each Season. You can see that the seasonal indexes vary from year to year for the same season. The simplest way to handle this is to compute an average index, as follows:

Quarter	Average Seasonal Index
Fall	$(1.2 + 1.238)/2 = 1.219$
Winter	$(1.15 + 1.048)/2 = 1.099$
Spring	$(0.95 + 0.905)/2 = 0.928$
Summer	$(0.70 + 0.810)/2 = 0.755$

Step 4 Calculate the Average Demand per Season for Next Year. We are told that the university forecast annual enrollment for the next year to be 90,000 students. The average demand per season, or quarter, is

$$90{,}000/4 = 22{,}500$$

Step 5 Multiply Next Year's Average Seasonal Demand by Each Seasonal Index. This last step will give us the forecast for each quarter of next year:

Quarter	Forecast (Students)
Fall	$22{,}500(1.219) = 27{,}428$
Winter	$22{,}500(1.099) = 24{,}728$
Spring	$22{,}500(0.928) = 20{,}880$
Summer	$22{,}500(0.755) = 16{,}988$

This can also be computed using a spreadsheet, as shown below. Notice slight differences in final numbers due to rounding.

	A	B	C	D	E	F
4		Enrollment (thousands)				
5	Quarter	Year 1	Year 2			
6	Fall	24	26			
7	Winter	23	22			
8	Spring	19	19			
9	Summer	14	17			
10	Total Demand	80	84			
11	Average Demand per Quarter	20	21			
12						
13	Calculate Seasonal Indices					
14		Individual				
15	Quarter	Year 1	Year 2	Average		
16	Fall	1.200	1.238	1.219		
17	Winter	1.150	1.048	1.099		
18	Spring	0.950	0.905	0.927		
19	Summer	0.700	0.810	0.755		
20						
21	Calculate Forecast for Next Year					
22	Estimated annual enrollment	90000				
23	Average per Quarter	22500				
24						
25	Expected Quarterly Enrollment, Based on Historical Seasonal Indices					
26	Quarter	Forecast				
27	Fall	27429				
28	Winter	24723				
29	Spring	20866				
30	Summer	16982				

C10: =SUM(C6:C9)

C11: =C10/4

B16: =B6/B$11 (copied down)

C16: =C6/C$11 (copied down)

D16: =(B16+C16)/2 (copied down)

B23: =B22/4

B27: =B$23*D16 (copied down)

LINKS TO PRACTICE

The Ski Industry Forecast

Forecasting demand at ski resorts such as Snowshoe, Holiday Valley, and Seven Springs can be very challenging because data are highly seasonal. Multiple seasonal factors need to be considered, including the month of the year, day of the week, and ho1idays and long weekends, in addition to considering the weather forecast. Historical data are used to develop the indexes for these seasons. In addition, the ski industry has been experiencing an upward trend over the past years, particularly with the growth of snow boarding. A simple way to make forecasts in this industry is to forecast the trend and then make adjustments based on developed seasonal indexes.

CAUSAL MODELS

Recall that causal, or associative, models assume that the variable we are trying to forecast is somehow related to other variables in the environment. The forecasting challenge is to discover the relationships between the variable of interest and these other variables. These relationships, which can be very complex, take the form of a mathematical model, which is used to forecast future values of the variable of interest. Some of the best-known causal models are regression models. In this section we look at linear and multiple regression and how they are used in forecasting.

Linear Regression

In **linear regression** the variable being forecast, called the dependent variable, is related to some other variable, called the independent variable, in a linear (or straight-line) way. Figure 8-2 shows how a linear regression line relates to the data. You can see

▶ **Linear regression**
Procedure that models a straight-line relationship between two variables.

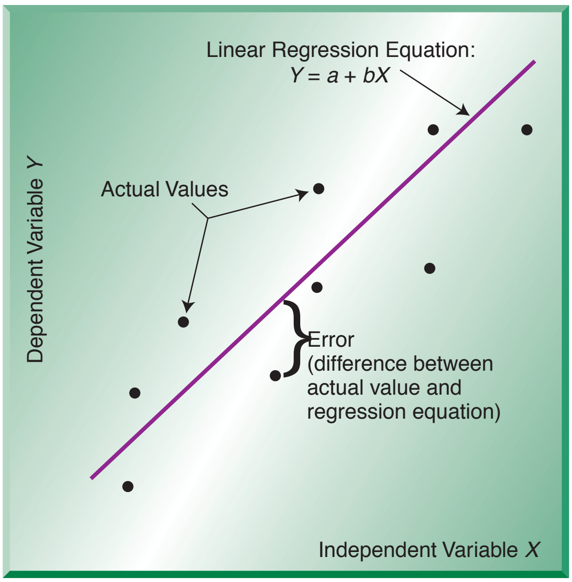


FIGURE 8-2

Linear regression line fit to historical data

that the dependent variable is linearly related to the independent variable. The relationship between two variables is the equation of a straight line:

$$Y = a + bX$$

where Y = dependent variable
X = independent variable
a = Y intercept of the line
b = slope of the line

Many straight lines could be drawn through the data. Linear regression selects parameters a and b, which define a straight line that minimizes the sum of the squared errors, or deviations from the line. This is called the *least-squares straight line*. Developing the values for a and b can be complicated, so we simply give their computation here. You can assume that computing a and b in this way will produce a straight line through the data that minimizes the sum of the squared errors. The steps in computing the linear regression equation are as follows:

Step 1 Compute parameter b:

$$b = \frac{\Sigma XY - n\overline{X}\overline{Y}}{\Sigma X^2 - n\overline{X}^2}$$

where $\overline{Y}$ = average of the Y values
$\overline{X}$ = average of the X values
n = number of data points

We compute parameter b first because that calculation is needed to compute parameter a.

Step 2 Compute parameter a:

$$a = \overline{Y} - b\overline{X}$$

Step 3 Substitute these values to obtain the linear regression equation:

$$Y = a + bX$$

Step 4 To make a forecast for the dependent variable (Y), substitute the appropriate value for the independent variable (X).

EXAMPLE 8.11

Forecasting with Linear Regression

A maker of personalized golf shirts has been tracking the relationship between sales and advertising dollars over the past four years. The results are as follows:

Sales Dollars (in thousands)	Advertising Dollars (in thousands)
130	32
151	52
150	50
158	55

Use linear regression to find out what sales would be if the company invested $53,000 in advertising for next year.

- **Before You Begin:** When using linear regression, always identify the independent and dependent variables. Remember that the dependent variable is the one you are trying to forecast.

- **Solution:**

In this example sales are the *dependent variable* (Y) and advertising dollars are the *independent variable* (X). We assume that there is a relationship between these two variables. To compute the linear regression equation, we set up the following table of information:

	Y	X	XY	X^2	Y^2
	130	32	4160	2304	16,900
	151	52	7852	2704	22,801
	150	50	7500	2500	22,500
	158	55	8690	3025	24,964
Total	**589**	**189**	**28,202**	**9,253**	**87,165**

$$\overline{X} = 47.25 \qquad \overline{Y} = 147.25$$

Now let's follow the steps necessary for computing a linear regression equation:

Step 1 Compute parameter b:

$$b = \frac{\Sigma XY - n\overline{XY}}{\Sigma X^2 - n\overline{X}^2} = \frac{28{,}202 - 4(47.25)(147.25)}{9{,}253 - 4(47.25)^2} = \frac{371.75}{322.75} = 1.15$$

Step 2 Compute parameter a:

$$a = \overline{Y} - b\overline{X} = 147.25 - (1.15)(47.25) = 92.83$$

Step 3 Compute the linear regression equation:

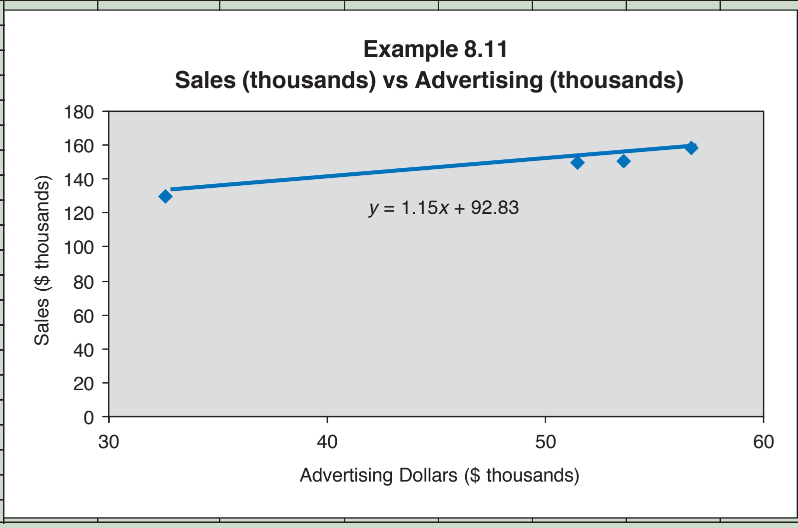
$$Y = a + bX$$
$$= 92.8[3] + 1.15X$$

Step 4 Now that we have the equation, we can compute the value of Y for any value of X. To compute the value of sales when advertising dollars are $53,000, we can substitute that number for X:

$$Y = 92.8[3] + 1.15(53) = \$153.87 \text{ (in thousands)}$$

This can also be computed using a spreadsheet, as shown here.

	A	B	C	D	E	F	G	H
4	Year	Advertising Dollars (thousands)	Sales (thousands)					
5	1	32	130					
6	2	52	151					
7	3	50	150					
8	4	55	158	C9: =AVERAGE(C5:C8)				
9	Average	47.25	147.25					
10				C11: =SLOPE(C5:C8,B5:B8)				
11	Slope Coefficient (b)		1.15	C12: =INTERCEPT(C5:C8,B5:B8)				
12	Intercept Coefficient (a)		92.83					



Correlation Coefficient

Correlation coefficient Statistic that measures the direction and strength of the linear relationship between two variables.

When performing linear regression, it is helpful to compute the **correlation coefficient**, which measures the direction and strength of the linear relationship between the independent and dependent variables. The correlation coefficient is computed using the following equation:

$$r = \frac{n(\Sigma XY) - (\Sigma X)(\Sigma Y)}{\sqrt{[n(\Sigma X^2) - (\Sigma X)^2]} \cdot \sqrt{[n(\Sigma Y^2) - (\Sigma Y)^2]}}$$

Although the equation seems complicated, it is easy to compute and the values of r can be easily interpreted. Values of r range between -1 and $+1$ and have the following meanings:

$r = +1$: There is a perfect positive linear relationship between the two variables. For every 1-unit increase in the independent variable, there is a 1-unit increase in the dependent variable.

$r = -1$: There is a perfect negative linear relationship between the two variables. Just because the relationship is negative does not mean that there is no relationship. It is still a linear relationship except that it is negative; the two variables move in opposite directions. A unit increase in the independent variable is accompanied by a unit decrease in the dependent variable.

$r = 0$: There is no linear relationship between the variables.

Obviously, the closer the value of r is to 1.00 or -1.00, the stronger is the linear relationship between the two variables. If we square the correlation coefficient, r^2, we can determine how well the independent variable explains changes in the dependent variable. This statistic shows how well the regression line "fits" the data. The higher the r, the better. A high r^2—say, 0.80 or higher—would indicate that the independent variable can be used effectively as a predictor of the dependent variable.

EXAMPLE 8.12

Computing the Correlation Coefficient

Using the information from Example 8.11, compute the correlation coefficient and evaluate the strength of the linear relationship between sales and advertising dollars.

- **Before You Begin:** To solve this problem, compute the correlation coefficient using the formula from the text. Remember that the closer the computed value is to 1, the stronger the relationship between the two variables.

- **Solution:**

Given our information, we can compute the correlation coefficient as follows:

$$r = \frac{n(\Sigma XY) - (\Sigma X)(\Sigma Y)}{\sqrt{[n(\Sigma X^2) - (\Sigma X)^2]} \cdot \sqrt{[n(\Sigma Y^2) - (\Sigma Y)^2]}}$$

$$= \frac{4(28{,}202) - (189)(589)}{\sqrt{[4(9{,}253) - (189)^2]} \cdot \sqrt{[4(87{,}165) - (589)^2]}} = 0.992$$

The computed correlation coefficient is close to 1, which means that there is a strong positive linear relationship between the two variables. Also, if we compute r^2, we get 0.984, which means that 98.4 percent of the variability in sales is explained by advertising dollars.

Multiple Regression

Multiple regression is an extension of linear regression. However, unlike in linear regression where the dependent variable is related to one independent variable, multiple regression develops a relationship between a dependent variable and multiple independent variables. The general formula for multiple regression is as follows:

$$Y = B_0 + B_1X_1 + B_2X_2 + \cdots + B_KX_K$$

where Y = dependent variable
B_0 = the Y intercept
$B_1 \ldots B_K$ = coefficients that represent the influence of the independent variables on the dependent variable
$X_1 \ldots X_K$ = independent variables

For example, the dependent variable might be sales and the independent variables might be number of sales representatives, number of store locations, area population, and per capita income.

Multiple regression is a powerful tool for forecasting and should be used when multiple factors influence the variable that is being forecast. However, multiple regression does significantly increase data and computational requirements needed for forecasting. Fortunately, most standard statistical software programs have multiple regression capabilities.

MEASURING FORECAST ACCURACY

One of the basic principles of forecasting is that forecasts are rarely perfect. However, how does a manager know how much a forecast can be off the mark and still be reasonable? One of the most important criteria for choosing a forecasting model is its accuracy. Also, data can change over time, and a model that once provided good results may no longer be adequate. The model's accuracy can be assessed only if forecast performance is measured over time. For all these reasons it is important to track model performance over time, which involves monitoring forecast errors.

Forecast Accuracy Measures

Forecast error is the difference between the forecast and actual value for a given period, or

$$E_t = A_t - F_t$$

where E_t = forecast error for period t
A_t = actual value for period t
F_t = forecast for period t

▶ **Forecast error**
Difference between forecast and actual value for a given period.

However, error for one time period does not tell us very much. We need to measure forecast accuracy over time. Two of the most commonly used error measures are the **mean absolute deviation** (***MAD***) and the **mean squared error** (***MSE***). *MAD* is the average of the sum of the absolute errors:

$$MAD \frac{\Sigma|\text{actual} - \text{forecast}|}{n}$$

MSE is the average of the squared error:

$$MSE = \frac{\Sigma(\text{actual} - \text{forecast})^2}{n}$$

▶ **Mean absolute deviation (*MAD*)**
Measure of forecast error that computes error as the average of the sum of the absolute errors.

▶ **Mean squared error (*MSE*)**
Measure of forecast error that computes error as the average of the squared error.

One of the advantages of *MAD* is that it is based on absolute values. Consequently, the errors of opposite signs do not cancel each other out when they are added. We sum the errors regardless of sign and obtain a measure of the average error. If we are comparing different forecasting methods, we can then select the method with the lowest *MAD*.

MSE has an additional advantage: due to the squaring of the error term, large errors tend to be magnified. Consequently, *MSE* places a higher penalty on large errors. This can be a useful error measure in environments in which large errors are particularly destructive. For example, a blood bank forecasts the demand for blood. Because forecasts are rarely perfect, there will be errors. However, in this environment a large error could be very damaging. Using *MSE* as an error measure would highlight any large errors in the blood bank's forecast. As with *MAD*, when comparing the forecast performance of different methods we would select the method with the lowest *MSE*.

To evaluate forecast performance, you need to use only one forecast error measure. However, a good forecaster learns to rely on multiple methods to evaluate forecast performance. Example 8.13 illustrates the use of *MAD* and *MSE*.

EXAMPLE 8.13

Measuring Forecast Accuracy

Standard Parts Corporation is comparing the accuracy of two methods that it has used to forecast sales of its popular valve. Forecasts using method A and method B are shown against the actual values for January through May. Which method provided better forecast accuracy?

- **Before You Begin:** In this problem you are to compare the forecast accuracy of two forecasting methods. Since a good forecaster relies on multiple error measures, compute both the *MAD* and *MSE* using the formulas given in the text. The method that gives the lowest *MAD* and *MSE* provides the better accuracy.

- **Solution:**

	Actual	Method A				Method B			
Month	**Sales**	**Forecast**	**Error**	**|Error|**	**Error²**	**Forecast**	**Error**	**|Error|**	**Error²**
January	30	28	2	2	4	30	0	0	0
February	26	25	1	1	1	28	−2	2	4
March	32	32	0	0	0	36	−4	4	16
April	29	30	−1	1	1	30	−1	1	1
May	31	30	1	1	1	28	3	3	9
Total			**3**	**5**	**7**		**−4**	**10**	**30**

Accuracy for method A:

$$MAD = \frac{\Sigma|\text{actual} - \text{forecast}|}{n} = \frac{5}{5} = 1$$

$$MSE = \frac{\Sigma(\text{actual} - \text{forecast})^2}{n} = \frac{7}{5} = 1.4$$

Accuracy for method B:

$$MAD = \frac{\Sigma|\text{actual} - \text{forecast}|}{n} = \frac{10}{5} = 2$$

$$MSE = \frac{\Sigma(\text{actual} - \text{forecast})^2}{n} = \frac{30}{5} = 6$$

Of the two methods, method A produced a lower *MAD* and a lower *MSE*, which means that it provides better forecast accuracy. Note that the magnitude of difference in values is greater for

MSE than for *MAD*. Recall that *MSE* magnifies large errors through the squaring process. For the month of March, method B had a magnitude of error that was much larger than for other periods, causing *MSE* to be high. This can also be computed using a spreadsheet, as shown next.

	A	B	C	D	E	F	G	H	I	J
4			Method A				Method B			
5	Month	Actual Sales	Forecast	Error	Absolute Error	Error^2	Forecast	Error	Absolute Error	Error^2
6	January	30	28	2	2	4	30	0	0	0
7	February	26	25	1	1	1	28	-2	2	4
8	March	32	32	0	0	0	36	-4	4	16
9	April	29	30	-1	1	1	30	-1	1	1
10	May	31	30	1	1	1	28	3	3	9
11	Totals			3	5	7		-4	10	30
12										
13				MAD =	1.0			MAD =	2.0	
14				MSE =	1.4			MSE =	6.0	
23										
24	Key Formulas (similar formulas for method B)									
25	D6	=$B6-C6 (copied down)								
26	E6	=ABS(D6) (copied down)								
27	F6	=D6^2 (copied down)								
28	E13	=AVERAGE(E6:E10)								
29	E14	=AVERAGE(F6:F10)								

Tracking Signal

When there is a difference between forecast and actual values, one problem is to identify whether the difference is caused by random variation or is due to a *bias* in the forecast. **Forecast bias** is a persistent tendency for a forecast to be over or under the actual value of the data. We cannot do anything about random variation, but bias can be corrected.

▶ **Forecast bias**
A persistent tendency for a forecast to be over or under the actual value of the data.

One way to control for forecast bias is to use a *tracking signal*. A **tracking signal** is a tool used to monitor the quality of the forecast. It is computed as the ratio of the algebraic sum of the forecast errors divided by *MAD*:

▶ **Tracking signal**
Tool used to monitor the quality of a forecast.

$$\text{Tracking signal} = \frac{\text{algebraic sum of forecast errors}}{MAD}$$

or

$$\text{Tracking signal} = \frac{\Sigma(\text{actual} - \text{forecast})}{MAD}$$

As the forecast errors are summed over time, they can indicate whether there is a bias in the forecast. To monitor forecast accuracy, the values of the tracking signal are compared against predetermined limits. These limits are usually based on judgment and experience and can range from ± 3 to ± 8. In this chapter we will use the limits of ± 4, which compare to limits of 3 standard deviations. If errors fall outside these limits, the forecast should be reviewed.

EXAMPLE 8.14

Developing a Tracking Signal

A company uses a tracking signal with limits of ±4 to decide whether a forecast should be reviewed. Compute the tracking signal given the following historical information and decide when the forecast should be reviewed. The *MAD* for this item was computed as 2.

Weeks	Actual	Forecast	Deviation	Cumulative Deviation	Tracking Signal
				4	2
1	8	10			
2	11	10			
3	12	10			
4	14	10			

- **Before You Begin:** In this problem you have to compute the tracking signal for weeks 1 through 4 and determine if it exceeds the set limit of ±4. Remember that the tracking signal is the sum of the forecast errors (the cumulative deviation) divided by the *MAD*. In this problem *MAD* has been computed as 2. You need to compute the cumulative deviation for each period and divide by the *MAD*.

- **Solution:**

			Cumulative	Tracking	
Weeks	**Actual**	**Forecast**	**Deviation**	**Deviation**	**Signal**
				4	2
1	8	10	−2	2	1
2	11	10	1	3	1.5
3	12	10	2	5	2.5
4	14	10	4	9	4.5

The forecast should be reviewed in week 4 because the tracking signal has exceeded +4.

SELECTING THE RIGHT FORECASTING MODEL

A number of factors influence the selection of a forecasting model. They include the following:

1. *Amount and type of available data.* Quantitative forecasting models require certain types of data. If there are not enough data in quantifiable form, it may be necessary to use a qualitative forecasting model. Also, different quantitative models require different amounts of data. Exponential smoothing requires a small amount of historical data, whereas linear regression requires considerably more. The amount and type of data available play a large role in the type of model that can be considered.
2. *Degree of accuracy required.* The type of model selected is related to the degree of accuracy required. Some situations require only rough forecast estimates, whereas others require precise accuracy. Often, the greater the degree of accuracy required, the higher is the cost of the forecasting process. This is because increasing accuracy means increasing the costs of collecting and processing data, as well as the cost of the computer software required. A simpler and less

costly forecasting model may be better overall than one that is very sophisticated but expensive.

3. *Length of forecast horizon.* Some forecasting models are better suited to short forecast horizons, whereas others are better for long horizons. It is very important to select the correct model for the forecast horizon being used. For example, a manufacturer that wishes to forecast sales of a product for the next three months will use a very different forecasting model than an electric utility that wishes to forecast demand for electricity over the next twenty-five years.
4. *Data patterns present.* It is very important to identify the patterns in the data and select the appropriate model. For example, lagging can occur when a forecasting model meant for a level pattern is applied to data with a trend.

FORECASTING SOFTWARE

Today much commercial forecasting is performed using computer software. Many software packages can be used for forecasting. Some can handle thousands of variables and manipulate huge databases. Others specialize in one forecasting model. Consequently, it may be difficult to select the right forecasting software. Most forecasting software packages fall into one of three categories: (1) spreadsheets, (2) statistics packages, and (3) specialty forecasting packages. In this section we look at the differences among these categories. Then we present some guidelines for selecting a software package for forecasting.

Spreadsheets

Spreadsheets, such as Microsoft Excel®, Quattro Pro®, and Lotus 1-2-3®, are prevalent in business, and most people are familiar with at least one of them. These packages provide basic forecast capability, such as simple exponential smoothing and regression. Also, simple forecasting programs can be written very quickly for most spreadsheet programs. However, the disadvantage of using spreadsheets for forecasting is that they do not have the capability for statistical analysis of forecast data. As we have seen, proper forecasting requires much data analysis. This involves analyzing the data for patterns, studying relationships among variables, monitoring forecast errors, and evaluating the performance of different forecasting models. Unfortunately, spreadsheets do not offer this capability as readily as packages designed specifically for forecasting.

Statistical Packages

Statistical software includes packages designed primarily for statistical analysis, such as SPSS, SAS, NCSS, and Minitab. Almost all of these packages also offer forecasting capabilities, as well as extensive data analysis capability. There are large differences among statistical packages, particularly between those versions for mainframe versus those for microcomputers. Overall, these packages offer large capability and a variety of options. However, their many features can be overwhelming for someone interested only in forecasting. Statistical software packages are best for a user who seeks many statistical and graphical capabilities in addition to forecasting features.

Specialty Forecasting Packages

Specialized forecasting software is specifically intended for forecasting use. These packages often provide an extensive range of forecasting capability, though they may not offer large statistical analysis capability. Popular packages include Forecast Master, Forecast Pro, SIBYL/Runner, Autobox, and SCA. Some of these packages offer a wide range of forecasting models, whereas others specialize in a particular model category. Forecasters who need extensive statistical analysis capability may need to use a statistical package in addition to the forecasting package.

Guidelines for Selecting Forecasting Software

There are many forecasting software packages to choose from, and the process can be overwhelming. Following are some guidelines for selecting the right package:[1]

1. *Does the package have the facilities you want?* The first question to ask is whether the forecasting methods you are considering using are available in the package. Other issues to consider are the software's graphics capabilities, data management, and reporting facilities. You need to consider how important these are given the purpose of the forecasts you will be generating.
2. *What platform is the package available for?* You obviously need to make sure that the software is available for the platform you are using. Also, it may be necessary to consider the availability for multiple platforms, depending on who will use the software and whether there will be transferring of files.
3. *How easy is the package to learn and use?* Some packages offer many capabilities but may be hard to use. Generally, the more comprehensive the array of capabilities, the more difficult the package is to use. Make sure that you can master the software. Also check the ease of importing and exporting data.
4. *Is it possible to implement new methods?* Often forecasters prefer to modify existing methods to fit their particular needs. Many forecasting packages allow the addition of new models or the modification of existing ones through a programming language.
5. *Do you require interactive or repetitive forecasting?* In many operations management situations we need to make forecasts for hundreds of items on a regular basis, such as monthly or quarterly. For these situations it is very useful to have a "batch" forecasting capability. This is not necessary, however, for forecasts that are generated interactively with the forecaster.
6. *Do you have very large data sets?* Almost all packages have a limit on how many variables and how many observations can be processed. Sometimes very powerful forecasting packages can handle only relatively small data sets. Make sure the package you purchase is capable of processing the data you need.
7. *Is there any local support?* Make sure there is ample documentation and good technical support, and check for any other local support that may be available. Remember that all packages can encounter glitches. A number of forecasting vendors offer seminars, and there are often courses that can be taken for the more popular methods, such as SAS and SPSS.

[1]S. Makridakis, S. Wheelwright, and R. Hyndman, *Forecasting Methods and Applications*, 3rd ed. (New York: John Wiley, 1998).

8. *Does the package give the right answers?* Most people assume that a computer package will generate correct results. However, this is not always the case. There are small differences in output between different packages due to differences in the algorithms used for computing. Some differences can result from actual errors in the programs, especially when large data sets are used. One recommendation is to compare output from the software against published results or against output from another package.

Another factor to consider is the *cost of the package* relative to the importance of its use. Some packages are very expensive and comprehensive, while others are less expensive. Evaluate the use of the forecasts generated and their importance in the managerial situation before purchasing a highly expensive package. Finally, you need to consider *compatibility with existing software*, especially for other operations management applications such as scheduling and inventory control. The output from forecasting usually feeds into these systems, so you need to make sure these systems can communicate with one another.

FOCUS FORECASTING

Focus forecasting is a forecasting approach that has gained some popularity in business. It was developed by Bernie Smith,[2] who argues that statistical methods do not work well for forecasting. He believes simple rules that have worked well in the past are best used to forecast the future. The idea behind focus forecasting is to test these rules on past data and evaluate how they perform. New rules can be added at any time, and old ones that have not performed well can be eliminated.

Focus forecasting uses a computer simulation program that evaluates the forecast performance of a number of rules on past data. The program keeps track of the rules and evaluates how well they perform. Following are some examples of rules:

1. We will sell over the next three months what we sold over the last three months.
2. What we sold in a three-month period last year, we will sell in the same three-month period this year.
3. We will sell over the next three months 5 percent of what we sold over the last three months.
4. We will sell over the next three months 15 percent of what we sold over the same three-month period last year.

You can see that these rules use commonsense concepts. In focus forecasting, managers can come up with any new rules that they believe reflect accurate forecasts in their business and then test their value on historical data.

Smith claims to have achieved great success with focus forecasting. He states that he has compared its accuracy to that of conventional methods, such as exponential smoothing, and that focus forecasting consistently provides superior results.

COMBINING FORECASTS

One approach to forecasting that has been shown to result in improved forecast accuracy is to combine forecasts from two or more different forecasting methods. Studies have shown that combining forecasts can lead to forecast accuracy that is better than

[2]Bernard T. Smith, *Focus Forecasting: Computer Techniques for Inventory Control* (Boston: CBI, 1984).

that of the individual forecasts. The forecasting methods that are combined should be different and can even be based on different information or data.

One of the simplest ways to combine is to use a simple average of the individual forecasts. Even though there are more sophisticated ways of combining, a simple average has been shown to be very effective in improving forecast accuracy.

LINKS TO PRACTICE

Combining Methods in Weather Forecasting

Ralph Wetmore/Stone/ Getty Images

The idea of relying on different types of forecasting methods and combining their results to get a final forecast has even been used by weather forecasters. Weather forecasting can be challenging, and many factors need to be considered, such as long-range trends and current weather fronts. Weather forecasters have been able to improve their forecast accuracy by combining the results of forecasts made at different time intervals. For example, a weather forecast for the upcoming weekend may be formulated by *combining* computer-generated forecasts made on the preceding Monday, Tuesday, and Wednesday. This method is called "ensemble forecasting" and has proven to be very successful.

COLLABORATIVE PLANNING, FORECASTING, AND REPLENISHMENT (CPFR)

Collaborative Planning, Forecasting, and Replenishment (CPFR) is a collaborative process between two trading partners that establishes formal guidelines for joint forecasting and planning. The premise behind CPFR is that companies can be more successful if they join forces to bring value to their customers, share risks of the marketplace, and improve their performances.

In previous chapters we learned about the benefits that can be attained by sharing information with suppliers and developing long-term relationships. CPFR is a formal way of achieving this. By implementing CPFR, trading partners jointly set forecasts, plan production, replenish inventories, and evaluate their success in the marketplace. The most complete form of CPFR utilizes a nine-step process:

1. *Establish collaborative relationships.* Buyers and sellers formally establish their relationship, including expectations and performance measures. This is usually reevaluated annually.
2. *Create a joint business plan.* Buyers and sellers develop a joint business plan.
3. *Create a sales forecast.* Sales forecasts are generated based on available data. This is usually done monthly or weekly.
4. *Identify exceptions for sales forecasts.* Items that are exceptions to the sales forecast are identified.
5. *Resolve/collaborate on exceptions to sales forecasts.* Buyers and sellers jointly investigate exceptions by analyzing shared data.
6. *Create order forecast.* An order forecast is generated that supports the shared sales forecast and joint business plan.

7. *Identify exceptions for order forecast.* Buyers and sellers jointly identify which items are exceptions to the order forecast.
8. *Resolve/collaborate on exceptions to order forecast.* Exceptions are identified and resolved by analyzing shared data.
9. *Generate order.* Usually performed weekly or daily.

Most of the outlined steps are performed on a weekly or monthly basis, and the agreement between parties is evaluated annually. You can see that a large amount of time is spent jointly identifying and reconciling exceptions, with the focus on supporting the jointly set business plan. Also, note that CPFR is an iterative process. That means that it is done over and over again.

CPFR has contributed to the success of many companies, including Wal-Mart, Target, Black & Decker, and Ace Hardware. The German-based manufacturer of household cleaners and home care products, Henkel KgaA, was able to significantly improve sales forecasts and reduce error rates in just six months by implementing CPFR.

FORECASTING WITHIN OM: HOW IT ALL FITS TOGETHER

Forecasts impact not only other business functions but all other operations decisions. Operations managers make many forecasts, such as the expected demand for a company's products. These forecasts are then used to determine product designs that are expected to sell (Chapter 2), the quantity of product to produce (Chapters 5 and 6), and the amount of supplies and materials that are needed (Chapter 12). Also, a company uses forecasts to determine future space requirements (Chapter 10), capacity and location needs (Chapter 9), and the amount of labor needed (Chapter 11). Forecasts drive strategic operations decisions, such as choice of competitive priorities, changes in processes, and large technology purchases (Chapter 3). Forecast decisions also serve as the basis for tactical planning, such as developing worker schedules (Chapter 11). Virtually all operations management decisions are based on a forecast of the future.

FORECASTING ACROSS THE ORGANIZATION

Forecasting is an excellent example of an activity that is critical to the management of all functional areas within a company. In business organizations, forecasts are made in virtually every function and at every organizational level. Budgets are set, resources allocated, and schedules made based on forecasts. Without a forecast of the future, a company would not be able to make any plans, including day-to-day and long-range plans. In this section we look at how forecasting affects some of the other functions of an organization.

Marketing relies heavily on forecasting tools to generate forecasts of demand and future sales. However, the marketing department also needs to forecast sizes of markets, new competition, future trends, and changes in consumer preferences. Most of the forecasting methods discussed in this chapter are used by marketing. Marketing often works in conjunction with operations to assess future demands.

Finance uses the tools of forecasting to predict stock prices, financial performance, capital investment needs, and investment portfolio returns. The accuracy of demand forecasts, in turn, affects the ability of finance to plan future cash flow and financial needs.

Information systems play an important role in the forecasting process. Today's forecasting requires sharing of information and databases not only within a business but also between business entities. Often companies share their forecasts or demand information with their suppliers. These capabilities would not be possible without an up-to-date information system.

Human resources relies on forecasting to determine future hiring requirements. In addition, forecasts are made of the job market, labor skill availability, future wages and compensation, hiring and layoff costs, and training costs. In order to recruit proper talent, it is necessary to forecast labor needs and availability.

Economics relies on forecasting to predict the duration of business cycles, economic turning points, and general economic conditions that affect business. Whenever a plan of action is required, that plan is based on some anticipation of the future—a forecast. Whether in business, industry, government, or in other fields such as medicine, engineering, and science, proper planning for the future starts with a good forecast.

THE SUPPLY CHAIN LINK

All entities of a supply chain are working to fulfill final customer demands. The forecast of demand is critical, as it affects all the plans made by each company in the supply chain. When entities of the supply chain make their forecasts independent of one another, they each have their own separate forecast of demand. The consequences of this are a mismatch between supply and demand because each company is working to fulfill a different level of demand. Consider that Dell starts its planning process with a forecast of future demand to determine the amount of components it needs to order. At the same time, Intel, which supplies Dell with microprocessors, needs to determine its production and inventory schedules. If Dell and Intel made their forecasts separately, their forecasts would be different and Intel would not be able to supply the exact amounts Dell needs. In contrast, when there is collaboration between suppliers and manufacturers in generating the forecast, all entities are responding to the same level of demand. A good example of this is the implementation of Collaborative Planning, Forecasting, and Replenishment (CPFR), which we discussed earlier in the chapter.

Chapter Highlights

1. Three basic principles of forecasting are: forecasts are rarely perfect; forecasts are more accurate for groups or families of items rather than for individual items; and forecasts are more accurate for shorter than longer time horizons.
2. The forecasting process involves five steps: decide what to forecast; evaluate and analyze appropriate data; select and test a forecasting model; generate the forecast; and monitor forecast accuracy.
3. Forecasting methods can be classified into two groups: *qualitative* and *quantitative*. Qualitative forecasting methods generate a forecast based on the subjective opinion of the forecaster. Some examples of qualitative methods include *executive opinion, market research*, and the *Delphi method*. Quantitative forecasting methods are based on mathematical modeling. They can be divided into two categories: *time series models* and *causal models*.
4. Time series models are based on the assumption that all the information needed for forecasting is contained in the time series of data. Causal models assume that the variable being forecast is related to other variables in the environment.
5. There are four basic patterns of data: *level* or *horizontal, trend, seasonality*, and *cycles*. In addition, data usually contain *random variation*. Some forecasting models that can be used to forecast the level of a time series are *naïve, simple mean, simple moving average, weighted moving average*, and *exponential smoothing*. Separate models are used to forecast trend, such as *trend-adjusted exponential smoothing*. Forecasting seasonality requires a procedure in which we compute a *seasonal index*, the percentage by which each season is above or below the mean.
6. A simple causal model is linear regression, in which a straight-line relationship is modeled between the variable

we are forecasting and another variable in the environment. The correlation coefficient is used to measure the strength of the linear relationship between these two variables.

7 Three useful measures of forecast accuracy are mean absolute deviation (*MAD*), mean square error (*MSE*), and a tracking signal.

8 There are four factors to consider when selecting a forecasting model: the amount and type of data available, the degree of accuracy required, the length of forecast horizon, and patterns present in the data.

Key Terms

forecasting 265
qualitative forecasting methods 267
quantitative forecasting methods 268
executive opinion 269
market research 269
Delphi method 269
time series models 270
time series 270
causal models 270
level or horizontal pattern 272
trend 272
seasonality 272
cycles 273
random variation 273
naïve method 273
simple mean or average 274
simple moving average (SMA) 275
weighted moving average 278
exponential smoothing model 279
trend-adjusted exponential smoothing 281
seasonal index 284
linear regression 287
correlation coefficient 290
forecast error 291
mean absolute deviation (*MAD*) 291
mean squared error (*MSE*) 291
forecast bias 293
tracking signal 293

Formula Review

Name	Formula
1. Naïve	$F_{t+1} = A_t$
2. Simple mean	$F_{t+1} = \dfrac{\Sigma A_t}{n}$
3. Moving average	$F_{t+1} = \dfrac{\Sigma A_t}{n}$
4. Weighted moving average	$F_{t+1} = \Sigma C_t A_t$
5. Exponential smoothing	$F_{t+1} = \alpha A_t + (1 - \alpha)F_t$
6. Trend-adjusted exponential smoothing	**Step 1:** Smoothing the level of the series: $S_t = \alpha A_t + (1 - \alpha)(S_{t-1} + T_{t-1})$ **Step 2:** Smoothing the trend: $T_t = \beta(S_t - S_{t-1}) + (1 - \beta)T_{t-1}$ **Step 3:** Forecast including trend: $FIT_{t+1} = S_t + T_t$
7. Seasonality	**Step 1:** Calculate the average demand for each season. **Step 2:** Compute a seasonal index for every season of every year for which you have data.
8. Linear trend line/linear regression	**Step 1:** Compute parameter b: $b = \dfrac{\Sigma XY - n\overline{X}\overline{Y}}{\Sigma X^2 - n\overline{X}^2}$ **Step 2:** Compute parameter a: $a = \overline{Y} - b\overline{X}$ **Step 3:** Obtain equation: $Y = a + bX$

Name	Formula
9. Correlation coefficient	$r = \dfrac{n(\Sigma XY) - (\Sigma X) - (\Sigma Y)}{\sqrt{[n(\Sigma X^2) - (\Sigma X)^2]} \cdot \sqrt{[n(\Sigma Y^2) - (\Sigma Y)^2]}}$
10. Forecast error	$E_t = A_t - F_t$
11. Mean absolute deviation	$MAD = \dfrac{\Sigma\lvert\text{actual} - \text{forecast}\rvert}{n}$
12. Mean squared error	$MSE = \dfrac{\Sigma(\text{actual} - \text{forecast})^2}{n}$
13. Tracking signal	$\text{Tracking signal} = \dfrac{\Sigma(\text{actual} - \text{forecast})}{MAD}$

Solved Problems

(See student companion site for Excel template.)

• Problem 1

Given the following data, calculate forecasts for months 4, 5, 6, and 7 using a three-month moving average and an exponential smoothing forecast with an alpha of 0.3. Assume a forecast of 61 for month 3:

Month	Actual Sales	Forecast 3-Month Moving Average	Forecast Exponential Smoothing
1	56		
2	76		
3	58		
4	67		
5	75		
6	76		
7			

• *Before You Begin:*

To use a three-period moving average, remember that you always have to compute the average of the latest three observations. As new data become available, drop off the oldest data. For the exponential smoothing part of this problem, before you begin make sure that you have the three pieces of information you need: the current period's forecast (61 for month 3), the current period's actual value (58), and a value for the smoothing coefficient ($\alpha = 0.3$).

• *Solution*

Month	Actual Sales	Forecast 3-Month Moving Average	Forecast Exponential Smoothing
1	56		
2	76		
3	58		
4	67	63.33	60.1
5	75	67.00	62.17
6	76	66.66	66.02
7		72.66	69.01

To compute the moving average forecasts:

$$F_{t+1} = \frac{\Sigma A_t}{n}$$

$$F_4 = \frac{A_1 + A_2 + A_3}{3} = \frac{56 + 76 + 58}{3} = 63.33$$

$$F_5 = \frac{A_2 + A_3 + A_4}{3} = \frac{76 + 58 + 67}{3} = 67.00$$

$$F_6 = \frac{A_3 + A_4 + A_5}{3} = \frac{58 + 67 + 75}{3} = 66.66$$

$$F_7 = \frac{A_4 + A_5 + A_6}{3} = \frac{67 + 75 + 76}{3} = 72.66$$

To compute the exponential smoothing forecasts:

$$F_{t+1} = \alpha A_t + (1 - \alpha)F_t$$

$$F_4 = \alpha A_3 + (1 - \alpha)F_3$$

$$F_4 = (0.30)(58) + (0.70)61 = 60.1$$

$$F_5 = (0.30)(67) + (0.70)60.1 = 62.17$$

$$F_6 = (0.30)(75) + (0.70)62.17 = 66.02$$

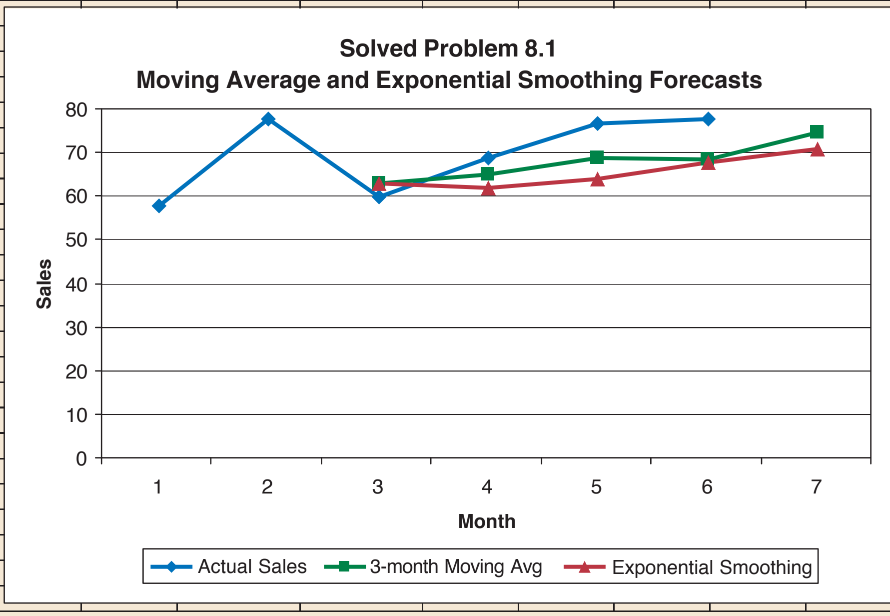
$$F_7 = (0.30)(76) + (0.70)66.02 = 69.01$$

This can also be computed using a spreadsheet, as shown here.

	A	B	C	D	E	F	G	H	I
4			alpha =	0.30					
5									
6			Forecasts						
7	Month	Actual Sales	3-month Moving Avg	Exponential Smoothing					
8	1	56							
9	2	76							
10	3	58	61	61					
11	4	67	63.33	60.10					
12	5	75	67.00	62.17					
13	6	76	66.67	66.02					
14	7		72.67	69.01					

C11: =AVERAGE(B8:B10) (copied down)

D11: =D$4*B10+(1-D$4)*D10 (copied down)



• Problem 2

True Beauty is a cosmetics company that uses exponential smoothing with trend to forecast monthly sales of its special face cream. At the end of November, the company wants to forecast sales for December. The trend through October has been 10 additional boxes sold per month. Average sales have been 60 boxes per month. The demand for November was 68 boxes. The company uses $\alpha = 0.20$ and $\beta = 0.10$. Make a forecast including trend for the month of December.

• *Before You Begin:*

Before you begin solving this type of problem, first identify the information given in the problem.

The information we have is:

$$S_{\text{Oct}} = 60 \text{ boxes/month}$$

$$T_{\text{Oct}} = 10 \text{ boxes/month}$$

$$A_{\text{Nov}} = 68 \text{ boxes}$$

$$\alpha = 0.20$$

$$\beta = 0.10$$

Now we can follow the three steps in the chapter for trend-adjusted exponential smoothing.

• *Solution*

We need to use three equations to generate a forecast including trend. For each equation we substitute the appropriate values:

Step 1 Smoothing the level of the series:

$$S_t = \alpha A_t + (1 - \alpha)(S_{t-1} + T_{t-1})$$

$$S_{\text{Nov}} = \alpha A_{\text{Nov}} + (1 - \alpha)(S_{\text{Oct}} + T_{\text{Oct}})$$

$$= (0.20) + (0.80)(60 + 10)$$

$$= 69.6$$

Step 2 Smoothing the trend:

$$T_t = \beta(S_t - S_{t-1}) + (1 - \beta)T_{t-1}$$

$$T_{\text{Nov}} = \beta(S_{\text{Nov}} + S_{\text{Oct}}) + (1 - \beta)T_{\text{Oct}}$$

$$= (0.1)(68) + (69 - 60) + (0.90)10$$

$$= 9.9$$

Step 3 Forecast including trend:

$$FIT_{t+1} = S_t + T_t$$

$$FIT_{\text{Dec}} = S_{\text{Nov}} + T_{\text{Nov}}$$

$$= 69 + 9.9$$

$$= 78.9 \text{ boxes}$$

• Problem 3

A gardener wants to develop a forecast for next year's quarterly sales of cactus trees. He has collected quarterly sales for the past two years and expects total sales for next year to be 500 cactus trees. The data clearly exhibit seasonality. How much can he expect to sell during each quarter of next year accounting for seasonality?

	Cactus Trees Sold	
Season	**Year 1**	**Year 2**
Fall	100	110
Winter	82	95
Spring	180	173
Summer	110	110
Total	**472**	**488**

• *Before You Begin:*

To solve this problem, follow the five steps given in the chapter for forecasting seasonality.

• *Solution*

We follow the steps used in developing seasonal indexes:

Step 1 Calculate the average demand for each season:

Year 1: 472/4 = 118

Year 2: 488/4 = 122

Step 2 Compute a seasonal index for every season of every year for which there are data.

	Cactus Trees Sold	
Season	**Year 1**	**Year 2**
Fall	100/118 = 0.847	110/122 = 0.902
Winter	82/118 = 0.695	95/122 = 0.778
Spring	180/118 = 1.53	173/122 = 1.42
Summer	110/118 = 0.932	110/122 = 0.902

Step 3 Calculate the average seasonal index for each season.

Season	Average Seasonal Index
Fall	(0.847 + 0.902)/2 = 0.875
Winter	(0.695 + 0.778)/2 = 0.737
Spring	(1.53 + 1.42/2 = 1.48
Summer	(0.932 + 0.902)/2 = 0.917

Step 4 Calculate the average demand per season for next year.

We are told that the sales forecast for next year is 500 cactus trees. The average demand per season, or quarter, is

$$500/4 = 125$$

Step 5 Multiply next year's average seasonal demand by each seasonal index.

Season	Forecast (Cactus Trees)
Fall	125(0.875) = 109.4
Winter	125(0.737) = 92.13
Spring	125(1.48) = 185.0
Summer	125(0.917) = 114.4

• Problem 4

A sneaker manufacturer has plotted sales of its most popular brand of sneakers over the past four months. Use a linear trend line to compute sales of sneakers for month 5.

• *Before You Begin:*

To solve this problem, follow the four steps given in the chapter for finding a linear trend line.

• *Solution*

	Month X	Sales Y	X^2	XY
	1	100	1	100
	2	120	4	240
	3	118	9	354
	4	125	16	500
Total	**10**	**463**	**30**	**1194**

$\bar{Y} = 115.75$ $\bar{X} = 2.5$

Step 1 Compute parameter b:

$$b = \frac{(\Sigma XY) - n\overline{XY}}{\Sigma X^2 - n\bar{X}^2}$$

$$= \frac{1194 - 4(2.5)(115.75)}{30 - 4(2.5)^2} = \frac{36.5}{5} = 7.3$$

Step 2 Compute parameter a:

$$a = \bar{Y} - b\bar{X} = 115.75 - (7.3)(2.5) = 97.5$$

Step 3 Compute the linear trend line.

$$Y = a + bX$$

$$Y = 97.5 + 7.3X$$

Step 4 For the fifth month, the value of sales would be

$$Y = 97.5 + 7.3(5) = 134 \text{ sneakers}$$

• Problem 5

A retailer of household appliances has collected data on the relationship between the company's sales and disposable household income. For the presented data:

(a) Obtain a linear regression equation for the data.

(b) Compute a correlation coefficient and determine the strength of the linear relationship.

(c) Use the linear regression equation to develop a forecast of sales if disposable household income is $37,800.

• *Before You Begin:*

To solve this problem follow the four steps given in the chapter for generating a forecast using linear regression. Make sure to clearly identify the independent and dependent variables. As you proceed, remember that you first compute parameter b, then parameter a, then develop the regression equation, and finally generate the forecast.

• *Solution*

	Sales (in 000s of $) Y	Disposable Household Income (in 000s of $) X	XY	X^2	Y^2
	29.8	16.8	500.6	282.2	888.0
	35.9	18.4	660.6	338.6	1,228.8
	38.8	20.4	791.5	416.2	1,505.4
	43.6	22.9	998.4	524.4	1,900.9
	46.8	25.7	1,202.8	660.5	2,190.2
	49.5	27.3	1,351.4	745.3	2,450.3
	52.3	32.1	1,678.8	1,030.4	2,735.3
	55.2	35.2	1,943.0	1,239.0	3,047.0
	57.2	36.3	2,076.4	1,317.7	3,271.8
	58.6	38.2	2,238.5	1,459.2	3,433.9
Total	**467.7**	**273.3**	**13,442.0**	**8,013.5**	**22,711.6**

$\bar{X} = 27.3$ $\bar{Y} = 46.8$

(a) **Step 1** Compute parameter b:

$$b = \frac{(\Sigma XY) - n\overline{XY}}{\Sigma X^2 - n\bar{X}^2} = \frac{13{,}442.0 - (10)(27.3)(46.8)}{8{,}013.5 - (10)(27.3)^2}$$

$$= 1.19$$

Step 2 Computer parameter a:

$$a = \bar{Y} - b\bar{X} = 46.8 - (1.19)(27.3) = 14.31$$

Step 3 Compute the linear regression line:

$$Y = a + bX$$

$$Y = 14.31 + 1.19X$$

(b) Computing the correlation coefficient:

$$r = \frac{n(\Sigma XY) - (\Sigma X)(\Sigma Y)}{\sqrt{n(\Sigma X^2) - (\Sigma X)^2} \cdot \sqrt{n(\Sigma Y^2) - (\Sigma Y)^2}}$$

$$r = \frac{10(13{,}442) - (273.3)(467.7)}{\sqrt{10(8{,}013.5) - (273.3)^2} \cdot \sqrt{10(22{,}711.6) - 467.7)^2}}$$

$$r = 0.977$$

The correlation coefficient is close to 1.00, indicating a strong positive linear relationship.

(c) $Y = 14.31 + 1.19\,(37.8) = 59.29$

This means that if disposable household income is $37,800, the company's sales are expected to be $59,290.

• Problem 6

A company is comparing the accuracy of two different forecasting methods. Use *MAD* to compare the accuracies of these methods for the past five weeks of sales. Which method provides greater forecast accuracy?

• *Before You Begin:*

Remember that *MAD* is the average of the sum of the absolute errors and that a *lower MAD* indicates better forecast accuracy.

• *Solution*

		Method A			Method B		
Week	**Actual Sales**	**Forecast**	**Error**	**|Error|**	**Forecast**	**Error**	**|Error|**
1	25	30	−5	5	30	−5	5
2	18	20	−2	2	16	2	2
3	26	23	3	3	25	1	1
4	28	29	−1	1	30	−2	2
5	30	25	5	5	28	2	2
Total			**0**	**16**		**−2**	**12**

Accuracy for method A:

$$MAD = \frac{\Sigma|\text{actual} - \text{forecast}|}{n} = \frac{16}{5} = 3.2$$

Accuracy for method B:

$$MAD = \frac{\Sigma|\text{actual} - \text{forecast}|}{n} = \frac{12}{5} = 2.4$$

Of the two methods, method B produced a lower *MAD*, which means that it provides greater forecast accuracy. Note, however, that the sum of the errors was actually 0 for method A, which shows how this error measure can be misleading.

Discussion Questions

1. Give three examples showing why a business needs to forecast.
2. Give three examples from your life in which you may forecast the future.
3. Describe the steps involved in forecasting.
4. Identify the key differences between qualitative and quantitative forecasting methods. Which is better in your opinion and why?
5. What are the main types of data patterns? Give examples of each type.
6. Describe the different assumptions of time series and causal models.
7. What are the differences among models that forecast the level, trend, and seasonality?
8. Explain why it is important to monitor forecast errors.
9. Explain some of the factors to be considered in selecting a forecasting model.

Problems

1. Sales for a product for the past three months have been 200, 350, and 287. Use a three-month moving average to calculate a forecast for the fourth month. If the actual demand for month 4 turns out to be 300, calculate the forecast for month 5.

2. Lauren's Beauty Boutique has experienced the following weekly sales:

Week	Sales
1	432
2	396
3	415
4	458
5	460

Forecast sales for week 6 using the naïve method, a simple average, and a three-period moving average.

3. Hospitality Hotels forecasts monthly labor needs.

(a) Given the following monthly labor figures, make a forecast for June using a three-period moving average and a five-period moving average.

Month	Actual Values
January	32
February	41
March	38
April	39
May	43

(b) What would be the forecast for June using the naïve method?
(c) If the actual labor figure for June turns out to be 41, what would be the forecast for July using each of these models?
(d) Compare the accuracy of these models using the mean absolute deviation (*MAD*).
(e) Compare the accuracy of these models using the mean squared error (*MSE*).

4. The following data are monthly sales of jeans at a local department store. The buyer would like to forecast sales of jeans for the next month, July.
(a) Forecast sales of jeans for March through June using the naïve method, a two-period moving average, and exponential smoothing with an $\alpha = 0.2$. (*Hint:* Use naïve to start the exponential smoothing process.)
(b) Compare the forecasts using *MAD* and decide which is best.
(c) Using your method of choice, make a forecast for the month of July.

Month	Sales
January	45
February	30
March	40
April	50
May	55
June	47

5. The manager of a small health clinic would like to use exponential smoothing to forecast demand for laboratory services in the facility. However, she is not sure whether to use a high or low value of α. To make her decision, she would like to compare the forecast accuracy of a high and low α on historical data. She has decided to use an $\alpha = 0.7$ for the high value and $\alpha = 0.1$ for the low value. Given the following historical data, which do you think would be better to use?

Week	Demand (lab requirements)
1	330
2	350
3	320
4	370
5	368
6	343

6. The manager of the health clinic in Problem 5 would also like to use exponential smoothing to forecast demand for emergency services in the facility. As in Problem 5, she is not sure whether to use a high or low value of α. To make her decision, she would like to compare the forecast accuracy of a high and low α on historical data. Again, she has decided to use an $\alpha = 0.7$ for the high value and $\alpha = 0.1$ for the low value.
(a) Given the following historical data, which value of α do you think would be better to use?
(b) Is your answer the same as in Problem 5? Why or why not?

Week	Demand (in patients serviced)
1	430
2	289
3	367
4	470
5	468
6	365

7. The following historical data have been collected representing sales of a product. Compare forecasts using a three-period moving average, exponential smoothing with a $\alpha = 0.2$, and linear regression. Using *MAD* and *MSE*, which forecasting model is best? Are your results the same using the two error measures?

Week	Demand
1	20
2	31
3	36
4	38
5	42
6	40

8. A manufacturer of printed circuit boards uses exponential smoothing with trend to forecast monthly demand of its product. At the end of December, the company wishes to forecast sales for January. The estimate of trend through November has been 200 additional boards sold per month. Average sales have been around 1000 units per month. The demand for December was 1100 units. The company uses $\alpha = 0.20$ and $\beta = 0.10$. Make a forecast including trend for the month of January.

9. Demand at Nature Trails Ski Resort has a seasonal pattern. Demand is highest during the winter, as this is the peak ski season. However, there is some ski demand in the spring and even fall months. The summer months can also be busy as visitors often come for summer vacation to go hiking on the mountain trails. The owner of Nature Trails would like to make a forecast for each season of the next year. Total annual demand has been estimated at 4000 visitors. Given the last two years of historical data, what is the forecast for each season of the next year?

	Visitors	
Season	Year 1	Year 2
Fall	200	230
Winter	1400	1600
Spring	520	580
Summer	720	831

10. Rosa's Italian restaurant wants to develop forecasts of daily demand for the next week. The restaurant is closed on Mondays and experiences a seasonal pattern for the other six

days of the week. Mario, the manager, has collected information on the number of customers served each day for the past two weeks. If Mario expects total demand for next week to be around 350, what is the forecast for each day of next week?

Day	Number of Customers Week 1	Week 2
Tuesday	52	48
Wednesday	36	32
Thursday	35	30
Friday	89	97
Saturday	98	99
Sunday	65	69

11. The president of a company was interested in determining whether there is a correlation between sales made by different sales teams and hours spent on employee training. These figures are shown.

Sales (in thousands)	Training Hours
25	10
40	12
36	12
50	15
11	6

(a) Compute the correlation coefficient for the data. What is your interpretation of this value?
(b) Using the data, what would you expect sales to be if training was increased to 18 hours?

12. The number of students enrolled at Spring Valley Elementary has been steadily increasing over the past five years. The school board would like to forecast enrollment for years 6 and 7 in order to better plan capacity. Use a linear trend line to forecast enrollment for years 6 and 7.

Year	Enrollment
1	220
2	245
3	256
4	289
5	310

13. Happy Lodge Ski Resorts tries to forecast monthly attendance. The management has noticed a direct relationship between the average monthly temperature and attendance.

(a) Given five months of average monthly temperatures and corresponding monthly attendance, compute a linear regression equation of the relationship between the two. If next month's average temperature is forecast to be 45 degrees, use your linear regression equation to develop a forecast.

Month	Average Temperature	Resort Attendance (in thousands)
1	24	43
2	41	31
3	32	39
4	30	38
5	38	35

(b) Compute a correlation coefficient for the data and determine the strength of the linear relationship between average temperature and attendance. How good a predictor is temperature for attendance?

14. Small Wonder, an amusement park, experiences seasonal attendance. It has collected two years of quarterly attendance data and made a forecast of annual attendance for the coming year. Compute the seasonal indexes for the four quarters and generate quarterly forecasts for the coming year, assuming annual attendance for the coming year to be 1525.

Quarter	Park Attendance (in thousands) Year 1	Year 2
Fall	352	391
Winter	156	212
Spring	489	518
Summer	314	352

15. Burger Lover Restaurant forecasts weekly sales of cheeseburgers. Based on historical observations over the past five weeks, make a forecast for the next period using the following methods: simple average, three-period moving average, and exponential smoothing with $\alpha = 0.3$, given a forecast of 328 cheeseburgers for the first week.

Week	Cheeseburger Sales
1	354
2	345
3	367
4	322
5	356

If actual sales for week 6 turn out to be 368, compare the three forecasts using *MAD*. Which method performed best?

16. A company uses exponential smoothing with trend to forecast monthly sales of its product, which show a trend pattern. At the end of week 5, the company wants to forecast sales for week 6. The trend through week 4 has been 20 additional cases sold per week. Average sales have been 85 cases per week. The demand for week 5 was 90 cases. The company uses $\alpha = 0.20$ and $\beta = 0.10$. Make a forecast including trend for week 6.

17. The number of patients coming to the Healthy Start maternity clinic has been increasing steadily over the past eight

months. Given the following data, use a linear trend line to forecast attendance for months 9 and 10.

Month	Clinic Attendance (in thousands)
1	3.4
2	3.9
3	4.5
4	5.0
5	5.8
6	5.9
7	6.5
8	6.7

18. Given the following data, use exponential smoothing with $\alpha = 0.2$ and $\alpha = 0.5$ to generate forecasts for periods 2 through 6. Use *MAD* and *MSE* to decide which of the two models produced a better forecast.

Period	Actual	Forecast
1	15	17
2	18	
3	14	
4	16	
5	13	
6	16	

19. Pumpkin Pies Galore is trying to forecast sales of pies for the month of December. Demand for pies in September, October, and November has been 230, 304, and 415, respectively. Edith, the company's owner, uses a three-period weighted moving average to forecast sales. Based on her experience, she chooses to weight September as 0.1, October as 0.3, and November as 0.6.

(a) What would Edith's forecast for December be?
(b) What would her forecast be using the naïve method?
(c) If actual sales for December turned out to be 420 pies, which method was better (use *MAD*)?

20. A company has used three different methods to forecast sales for the past five months. Use *MAD* and *MSE* to evaluate the performance of the three methods.

(a) Which forecasting method performed best? Do *MAD* and *MSE* give the same results?

Period	Actual	Method A	Method B	Method C
1	10	10	9	8
2	8	11	10	11
3	12	12	8	10
4	11	13	12	11
5	12	14	11	12

(b) Which of these is actually the naïve method?

21. Two different forecasting models were used to forecast sales of a popular soda on a college campus. Actual demand and the two sets of forecasts are shown. Use *MAD* to explain which method provided a better forecast.

Period	Actual Demand	Forecast 1	Forecast 2
1	90	78	87
2	87	85	88
3	92	84	90
4	95	92	97
5	98	100	102
6	98	102	101

22. A producer of picture frames uses a tracking signal with limits of ±4 to decide whether a forecast should be reviewed. Given historical information for the past four weeks, compute the tracking signal and decide whether the forecast should be reviewed. The *MAD* for this item was computed as 2.

Weeks	Actual Sales	Forecast	Deviation	Cumulative Deviation	Tracking Signal
				6	3
1	12	11			
2	14	13			
3	14	14			
4	16	14			

23. Mop and Broom Manufacturing has tracked the number of units sold of their most popular mop over the past 24 months. This is shown.

Month	Sales	Month	Sales	Month	Sales
1	239	9	310	17	369
2	248	10	335	18	378
3	256	11	348	19	367
4	260	12	353	20	383
5	271	13	355	21	394
6	280	14	368	22	393
7	295	15	379	23	405
8	305	16	358	24	412

(a) Develop a linear trend line for the data.
(b) Compute a correlation coefficient for the data and evaluate the strength of the linear relationship.
(c) Using the linear trend line equation, develop a forecast for the next period, month 25.

24. Given the sales data from Problem 23, generate forecasts for months 7–24 using a six-period and a three-period moving average. Use *MAD* to compare the forecasts. Which forecast is more stable? Which is more responsive and why?

25. The following data were collected on the study of the relationship between a company's retail sales and advertising dollars:

Retail Sales ($)	Advertising ($)
29,789	16,893
35,434	18,398
38,732	20,376
43,585	22,982
46,821	25,732
49,283	27,281
52,271	32,182
55,289	35,298
57,298	36,281
58,293	38,178

(a) Obtain a linear regression line for the data.
(b) Compute a correlation coefficient and determine the strength of the linear relationship.
(c) Using the linear regression equation, develop a forecast of retail sales for advertising dollars of $40,000.

CASE: Bram-Wear

Lenny Bram, owner and manager of Bram-Wear, was analyzing performance data for the men's clothing retailer. He was concerned that inventories were high for certain clothing items, meaning that the company would potentially incur losses due to the need for significant markdowns. At the same time, it had run out of stock for other items early in the season. Some customers appeared frustrated by not finding the items they were looking for and needed to go elsewhere. Lenny knew that the problem, though not yet serious, needed to be addressed immediately.

Background

Bram-Wear was a retailer that sold clothing catering to young, urban, professional men. It primarily carried upscale, casual attire, as well as a small quantity of outerwear and footwear. Its success did not come from carrying a large product variety, but from a very focused style with an abundance of sizes and colors.

Bram-Wear had extremely good financial performance over the past five years. Lenny had attributed the company's success to a group of excellent buyers. The buyers seemed able to accurately target the style preferences of their customers and correctly forecast product quantities. One challenge was keeping up with customer buying patterns and trends.

The Data

To determine the source of the problem, Lenny had requested forecast and sales data by product category. Looking at the sheets of data, it appeared that the problem was not with the specific styles or items carried in stock; rather, the problem appeared to be with the quantities ordered by the buyers. Specifically, the problem centered on two items: an athletic shoe called Urban Run and the five-pocket cargo jeans.

Urban Run was a popular athletic shoe that had been carried by Bram-Wear for the past four years. Quarterly data for the past four years are shown in the table. The company seemed to always be out of stock of this athletic shoe. The model used by buyers to forecast sales for this item had been seasonal exponential smoothing. Looking at the data, Lenny wondered if this was the best method to use. It seemed to work well in the beginning, but now he was not so sure.

The data for the five-pocket cargo jean seemed also to point to a forecasting problem. When the product was introduced last year, it was expected to have a large upward trend. The buyers believed the trend would continue and used an exponential smoothing model with trend to forecast sales. However, they seemed to have too much inventory of this product. As with the Urban Run athletic shoe, Lenny wondered if the right forecasting model was being applied to the data. It seemed he would have to dig out his old operations management text to solve this problem.

Demand for Urban Run Athletic Shoe

Quarter	Year 1 Demand	Year 2 Demand	Year 3 Demand	Year 4 Demand
I	10	14	20	30
II	29	31	26	31
III	26	29	28	33
IV	15	18	30	35

Demand for 5-Pocket Cargo Jeans

Month	Year 1 Demand	Year 2 Demand
January	36	98
February	42	101
March	56	97
April	75	99
May	85	100
June	94	95
July	101	107
August	108	104
September	105	98
October	114	104
November	111	100
December	110	102

Case Questions

1. Is seasonal exponential smoothing the best model for forecasting Urban Run athletic wear? Why?

2. Explain what has happened to the data for Urban Run. What are the consequences of continuing to use seasonal exponential smoothing? What model would you use? Generate a forecast for the four quarters of the fourth year using your model. Determine your forecast error and the inventory consequences.

3. Is exponential smoothing with trend the best model for forecasting five-pocket cargo jeans? Why?

4. What method would you use to forecast monthly cargo jean demand for the second year given the previous year's monthly demand? Explain why you selected your approach. Generate the forecasts for each month of the second year with your method. Determine your forecast error and the inventory consequences.

CASE: The Emergency Room (ER) at Northwest General (A)

Jenn Kostich is the new department director for emergency services at Northwest General Hospital. One of her responsibilities is to ensure proper staffing in the emergency room (ER) by scheduling nurses to appropriate shifts. This has historically been a problem for the ER. The former director did not base nurse schedules on forecasts, but used the same fixed schedule week after week.

Jenn had recently received her degree in operations management. She knew that schedules needed to be based on forecasts of demand. She needed to start by analyzing historical data in order to determine the best forecasting method to use. Jenn's assistant provided her with information on patient arrivals in the ER by hour and day of the week for the previous month, October. October was considered a typical month for the ER, and Jenn thought it was a good starting point. Jenn reviewed the information (shown in the chart) that she had requested and wondered where to begin.

Hourly Patient Arrivals in the ER

Day of Week	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F
Day of Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Time (hr)																															
01	1	1	2	1	1	0	1	1	0	2	2	2	0	1	0	1	2	1	0	0	1	0	1	0	1	0	1	0	0	0	0
02	0	1	2	1	1	0	0	0	0	3	1	2	0	1	2	1	2	1	2	0	1	3	1	2	1	0	0	1	1	1	0
03	4	2	1	3	1	1	0	3	3	0	0	1	1	0	2	3	0	2	0	1	0	1	0	2	3	2	0	1	2	1	2
04	2	4	3	3	3	1	1	3	4	0	3	3	1	1	3	3	0	3	3	2	3	2	1	0	3	3	0	2	3	1	2
05	0	2	1	3	3	1	1	1	3	3	3	3	1	1	3	2	4	3	4	0	2	3	1	4	2	4	2	3	3	1	4
06	1	2	2	3	2	0	1	1	1	4	3	2	1	0	0	2	2	2	3	1	2	1	3	1	0	1	0	1	1	0	0
07	1	0	0	0	2	3	2	0	1	2	1	3	2	3	2	1	1	0	1	1	1	2	0	0	0	1	1	1	2	2	1
08	1	1	1	2	2	2	1	1	3	1	0	2	3	1	3	0	0	4	1	4	0	2	2	2	2	3	1	0	2	1	2
09	2	2	1	1	2	1	1	3	4	1	2	2	1	2	3	2	1	0	3	0	1	3	1	2	4	3	1	1	4	3	2
10	3	2	4	3	5	0	1	3	3	4	3	1	1	0	4	2	5	4	4	1	1	4	0	3	4	4	4	2	3	0	3
11	2	4	5	6	4	2	3	2	3	5	5	4	1	2	1	3	4	6	5	2	3	2	3	5	2	4	0	4	3	2	4
12	3	3	4	5	5	1	4	2	2	3	6	3	0	3	2	4	4	6	4	0	4	2	2	5	4	5	2	3	2	3	5
13	5	6	4	3	5	4	3	4	2	4	4	6	3	4	3	5	5	2	6	4	5	3	4	4	5	6	4	3	2	4	5
14	5	4	6	4	6	4	4	5	4	4	4	4	4	3	5	4	5	4	6	3	3	5	5	5	6	6	3	4	5	3	5
15	4	4	5	5	5	3	4	5	3	2	6	5	3	5	5	4	6	5	4	3	4	5	3	6	6	4	3	5	5	5	6
16	2	3	5	4	5	3	3	3	2	4	4	5	3	2	3	4	5	4	5	3	3	3	3	0	0	1	2	2	0	2	2
17	0	1	4	4	5	3	2	0	2	5	4	4	3	3	2	0	5	4	5	3	2	3	2	2	1	1	3	1	1	3	0
18	2	3	2	2	2	2	1	3	1	4	3	2	3	2	1	3	0	2	3	2	3	0	2	3	2	3	2	0	2	3	3
19	1	2	2	0	0	0	1	2	4	1	2	2	1	1	1	2	2	0	1	1	1	1	0	5	4	5	2	3	3	1	5
20	3	1	2	0	0	1	1	1	3	3	3	1	1	0	2	1	3	1	1	2	0	2	1	5	4	5	1	3	3	0	5
21	4	5	4	5	3	3	1	5	1	4	0	2	2	2	5	4	3	4	0	0	1	5	2	2	4	0	2	0	3	4	1
22	3	2	4	6	5	2	0	4	0	3	5	5	2	3	3	3	6	6	5	2	0	3	4	3	4	5	3	0	5	3	3
23	4	1	5	6	5	3	3	3	3	5	4	4	2	4	2	2	6	6	6	3	2	3	3	6	6	5	0	1	3	2	6
24	4	0	3	4	3	3	3	3	3	2	5	6	4	0	2	0	2	4	5	3	0	1	0	6	6	6	3	2	1	0	6

Case Questions

1. What is your opinion of the level at which the data are being collected? What are some of the advantages of collecting data at this level?

2. Aggregate the original data for October as you see appropriate (e.g., sum up by day of week, time of day, week of the month, etc.). This will give you a new data set to work with. Analyze your data for patterns. Can you find any?

3. Use at least two different forecasting models on the new data set you developed in question 2 by aggregating the original data. Compare their forecast performance and provide an evaluation.

INTERACTIVE CASE Virtual Company

www.wiley.com/college/reid

On-line Case: Cruise International, Inc.

Assignment: *Forecasting at Cruising Inernational, Inc.* In this assignment you will focus on forecasting demand for cruises in different geographical regions. CII is trying to determine which regions have faster-growing demand so that they can be sure to have sufficient cruises available in each specific region. You are to meet with Jean Burkette, Director of Demand Management, at CII corporate. Your meeting ends with Jean saying, "I need you to develop a forecast for the upcoming cruising season … using any method that you believe provides a reliable forecast." This assignment will enhance your knowledge of the material in Chapter 8 of your textbook while preparing you for future assignments.

To access the Web site:

- Go to **www.wiley.com/college/reid**
- Click **Student Companion Site**
- Click **Virtual Company**
- Click **Consulting Assignments**
- Click **Forecasting at CII**

INTERNET CHALLENGE On-line Data Access

You have been hired by a government agency to collect and analyze economic data and generate economic forecasts. Since you do not have much experience in this area, your manager, Ms. Hernandez, has decided to give you a chance to practice your skills. Ms. Hernandez believes that it would be a good idea for you to use the Internet to collect and monitor a sample of economic data. She has given you a list of Web sites to access. Your first assignment is to collect a sample of local, national, or international economic data from one of these sites. Next, try to analyze the data you have collected and identify any patterns. Then, using one of the techniques discussed in the chapter, generate a forecast for the future. Finally, as new data are posted, evaluate your performance using the error measures discussed in the chapter. How did you do, and what have you learned about the data you collected?

Web sites:

1. Census Bureau—provides economic and demographic information from the U.S. economy (http://www.census.gov/)

2. Penn World Tables—provides international economic data (http://www.hbs.edu/units/bgie/internet/penn.html)

3. Regional Economic Information System—provides regional, state, and local data (http://www.ciesin.org/datasets/reis/reis-home.html)

4. Resources for Economists on the Internet—provides business and economic data (http://www.rfe.org)

On-line Resources

Companion Website www.wiley.com/college/reid

- Take interactive *practice quizzes* to assess your knowledge and help you study in a dynamic way
- Review *PowerPoint slides* or print slides for notetaking
- Download *Excel Templates* to use for problem solving
- Access the *Virtual Company: Cruise International, Inc.*
- Find links to *Company Tours* for this chapter
  Artesyn Communication Products, LLC
  Ercol Furniture
- Find links for *Additional Web Resources* for this chapter
  Forecasting Principles, *www.forecastingprinciples.org*
  Institute of Business Forecasters, *www.ibf.org*
  International Institute of Forecasting, *www.ms.ic.ac.uk/iif/index.htm*

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CHAPTER 9

Capacity Planning and Facility Location

Before studying this chapter you should know or, if necessary, review

1. Globalization, Chapter 1, p. 18.
2. Differences between strategic and tactical decisions, Chapter 1, p. 9.
3. Break-even analysis, Chapter 3, pp. 59–60.
4. Qualitative forecasting methods, Chapter 8, pp. 268–270.

LEARNING OBJECTIVES

After studying this chapter you should be able to

1. Define capacity planning.
2. Define location analysis.
3. Describe the relationship between capacity planning and location and their importance to the organization.
4. Explain the steps involved in capacity planning and location analysis.
5. Describe the decision support tools used in capacity planning.
6. Identify key factors in location analysis.
7. Describe the decision support tools used in location analysis.

CHAPTER OUTLINE

WHAT'S IN OM FOR ME?

ACC FIN MKT OM HRM MIS

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Have you ever signed up for a course at your college or university only to find out that it is closed? Have you ever attended a class that was held in a remote location and found that the room was overcrowded? Most of us have had these experiences as students. These examples illustrate problems of poor capacity planning and location—problems that can greatly affect the success of a business. Students have been known to drop out of a course that is uncomfortable to sit in, difficult to get to, or even to leave a program in which courses are frequently closed. Similarly, businesses can lose customers by not being able to produce enough goods or by being in an inconvenient location.

Matching the capacity of a business with customer demand can be a challenge. Having too much capacity is just as problematic as not having enough capacity. The first leads to excess cost from having idle facilities, workers, and equipment. The second leads to lost sales as the company cannot satisfy customer demands.

After the terrorist attacks of September 11, 2001, many firms in the hospitality industry found themselves with excess capacity. This included such businesses as hotels, airlines, cruise ships, and amusement parks. Many of these companies, such as the Marriott Corporation, Walt Disney Company, and Carnival Cruises, offered promotional incentives to increase customer demand. Similarly, after the SARS epidemic in 2003 many international airlines offered large discounts on fares as they found themselves with excess capacity in the form of idle aircraft.

Capacity planning and location analysis are actually two separate decisions. Capacity planning deals with the maximum output rate that a facility can have, determined by the size of facilities and equipment. Location analysis, on the other hand, deals with the best location for a facility. You can probably see why these two decisions are usually made simultaneously. When a company decides to open a new facility, it must also decide on both the size of the facility and its location. The size of the facility may also be affected by the location.

In this chapter we will learn about both capacity planning and location analysis. We will see how companies make both kinds of decisions. We will also see how both of these issues can affect not only the success of a company but your everyday life as well.

CAPACITY PLANNING

▶ **Capacity**
The maximum output rate that can be achieved by a facility.

FIN

Capacity can be defined as the maximum output rate that can be achieved by a facility. The facility may be an entire organization, a division, or only one machine. Planning for capacity in a company is usually performed at two levels, each corresponding to either strategic or tactical decisions, as discussed in Chapter 1. The first level of capacity decisions is strategic and long-term in nature. This is where a company decides what investments in new facilities and equipment it should make. Because these decisions are strategic in nature, the company will have to live with them for a long time. Also, they require large capital expenditures and will have a great impact on the company's ability to conduct business. The second level of capacity decisions is more tactical in nature, focusing on short-term issues that include planning of workforce, inventories, and day-to-day use of machines. In this chapter we focus on long-term, strategic capacity decisions. Short-term capacity decisions are discussed in Chapter 14.

Why Is Capacity Planning Important?

▶ **Capacity planning**
The process of establishing the output rate that can be achieved by a facility.

Capacity planning is the process of establishing the output rate that can be achieved by a facility. If a company does not plan its capacity correctly, it may find that it either does not have enough output capability to meet customer demands or has too much capacity sitting idle. In our university example, that would mean either not being able to offer enough courses to accommodate all students or having too few students in the classrooms. Both cases are costly to the university. Another example is a bakery. Not having enough capacity would mean not being able to produce enough baked goods to meet sales. The bakery would often run out of stock, and customers might start going somewhere else. Also, the bakery would not be able to take advantage of the true demand available. On the other hand, if there is too much capacity, the bakery would incur the cost of an unnecessarily large facility that is not being used, as well as much higher operating costs than necessary.

LINKS TO PRACTICE

Capacity Planning in the ER

Masterfile

A hospital emergency room (ER) exemplifies the challenges of capacity planning. The problems of over- or undercapacity we just discussed also occur in the ER, only with potentially dire consequences. A number of factors contribute to the capacity of the ER. One is the number of beds and the amount of space available. If there are not enough beds, patients may have to wait long periods of time to be examined. Too many empty beds, on the other hand, result in wasted space.

Another factor affecting the ER's capacity is the number of nurses and doctors scheduled to work on a shift. If not enough staff is available, patients may not have anyone to treat them. The consequences of not having enough capacity can be grave. However, scheduling more staff than needed results in excess capacity in the form of highly paid professionals not having anything to do.

Capacity planning problems are notorious in the ER, partly due to high fluctuations in demand and the high costs of insufficient capacity. In fact, the American College of Emergency Physicians estimates that 62 percent of U.S. emergency rooms are at or above capacity. Particularly troubling are long patient waiting times that average over 47 minutes before a doctor is seen but can be as long as many hours. Many ERs are looking at ways to address this problem. One alternative being implemented is to immediately screen patients and identify those with minor ailments. These patients are then put into a "fast-track" category to be quickly treated and released. This technique serves to free up capacity for those patients that need it.

Planning for capacity is important if a company wants to grow and take full advantage of demand. At the same time, capacity decisions are complicated because they require long-term commitments of expensive resources, such as large facilities. Once these commitments have been made, it is costly to change them. Think about a business that purchases a larger facility in anticipation of an increase in demand, only to find that the demand increase does not occur. It is then left with a huge expense, no return on its investment, and the need to decide how to use a partially empty facility. Recall from Chapter 8 that forecasting future demands entails a great deal of uncertainty and risk; this makes long-term facility purchases inherently risky.

Another issue that complicates capacity planning is the fact that capacity is usually purchased in "chunks" rather than in smooth increments. Facilities, such as buildings and equipment, are acquired in large sizes, and it is virtually impossible to achieve an exact match between current needs and needs based on future demand. You can see this in the classroom example. If a university anticipates a large demand for a particular course, it may offer multiple sections. Each additional section adds capacity in chunks equal to one class size. If one class can hold a maximum of 45 students, opening up another class means adding capacity for up to an additional 45 students. The university must consider its forecast of the additional demand for the course. If the forecast for additional demand is only 4 additional students, the university will probably not open up another section. The reason is that the cost for each section takes the form of chunks that include the room, the instructor, and utilities. This cost is the same whether 1 student or 45 students attend.

Because of the uncertainty of future demand, the overriding capacity planning decision becomes one of whether to purchase a larger facility in anticipation of greater demand or to expand in slightly smaller but less efficient increments. Each strategy has its advantages and disadvantages. Think about a young married couple who want to purchase a home. They can purchase a very small home that would be more affordable, knowing that if they have children they eventually will need to face the disruption and cost of moving. On the other hand, if they purchase a larger home now they will be better prepared for the future but will be paying for additional space that they currently do not need.

Measuring Capacity

Although our definition of capacity seems simple, there is no one way to measure it. Different people have different interpretations of what capacity means, and the units of measurement are often very different. Table 9-1 shows some examples of how capacity might be measured by different organizations.

TABLE 9-1

Examples of Different Capacity Measures

Type of Business	Input Measures of Capacity	Output Measures of Capacity
Car manufacturer	Labor hours	Cars per shift
Hospital	Available beds per month	Number of patients per month
Pizza parlor	Worker hours per day	Number of pizzas per day
Ice-cream manufacturer	Operational hours per day	Gallons of ice cream per day
Retail store	Floor space in square feet	Revenues per day

Note that each business can measure capacity in different ways and that capacity can be measured using either inputs or outputs. Output measures, such as the number of cars per shift, are easier to understand. However, they do not work well when a company produces many different kinds of products. For example, if we operate a bakery that bakes only pumpkin pies, then a measure such as pies per day would work well. However, if we made many different kinds of pies and varied the combination from one day to the next, then simply using pies per day as our measure would not work as well, especially if some pies took longer to make than others. Suppose that pecan pies take twice as long to make as pumpkin pies. If one day we made 20 pumpkin pies and the next day we made 10 pecan pies, using *pies per day* as our measure would make it seem as if our capacity was underutilized on the second day, even though it was equally utilized on both days. When a company produces many different kinds of products, input measures work better.

When discussing the capacity of a facility, we need two types of information. The first is the *amount of available capacity*, which will help us understand how much capacity our facility has. The second is *effectiveness of capacity use*, which will tell us how effectively we are using our available capacity. Next we look at how to quantify and interpret this information.

E. Dygas/Taxi/Getty Images, Inc.

Overcrowding is a sign of insufficient capacity.

Measuring Available Capacity Let's return to our bakery example for a moment. Suppose that on the average we can make 20 pies per day. However, if we are really pushed, such as during holidays, maybe we can make 30 pies per day. Which of these is our true capacity? We can make 30 pies per day at a maximum, but we cannot keep up that pace for long. Saying that 30 per day is our capacity would be misleading. On the other hand, saying that 20 pies per day is our capacity does not reflect the fact that we can, if necessary, push our production to 30 pies.

Through this example you can see that different measures of capacity are useful because they provide different kinds of information. Following are two of the most common measures of capacity:

▶ **Design capacity**
The maximum output rate that can be achieved by a facility under ideal conditions.

Design capacity is the maximum output rate that can be achieved by a facility under ideal conditions. In our example, this is 30 pies per day. Design capacity can be sustained only for a relatively short period of time. A company achieves this output rate by using many temporary measures, such as overtime, overstaffing, maximum use of equipment, and subcontracting.

Effective capacity is the maximum output rate that can be sustained under normal conditions. These conditions include realistic work schedules and breaks, regular staff levels, scheduled machine maintenance, and none of the temporary measures that are used to achieve design capacity. Note that effective capacity is usually lower than design capacity. In our example, effective capacity is 20 pies per day.

▶ **Effective capacity**
The maximum output rate that can be sustained under normal conditions.

Measuring Effectiveness of Capacity Use Regardless of how much capacity we have, we also need to measure how well we are utilizing it. **Capacity utilization** simply tells us how much of our capacity we are actually using. Certainly there would be a big difference if we were using 50 percent of our capacity, meaning our facilities, space, labor, and equipment, rather than 90 percent. Capacity utilization can simply be computed as the ratio of actual output over capacity:

▶ **Capacity utilization**
Percentage measure of how well available capacity is being used.

$$\text{Utilization} = \frac{\text{actual output rate}}{\text{capacity}}(100\%)$$

However, since we have two capacity measures, we can measure utilization relative to either design or effective capacity:

$$\text{Utilization}_{\text{effective}} = \frac{\text{actual output}}{\text{effective capacity}}(100\%)$$

$$\text{Utilization}_{\text{design}} = \frac{\text{actual output}}{\text{design capacity}}(100\%)$$

EXAMPLE 9.1

Computing Capacity Utilization

In the bakery example, we have established that design capacity is 30 pies per day and effective capacity is 20 pies per day. Currently, the bakery is producing 27 pies per day. What is the bakery's capacity utilization relative to both design and effective capacity?

- **Before You Begin:** To compute capacity utilization, you need to calculate the ratio of actual output (27 pies per day) over capacity. The difference between the two capacity measures is that one uses effective capacity (20 pies per day) and the other uses design capacity (30 pies per day).

- **Solution:**

$$\text{Utilization}_{\text{effective}} = \frac{\text{actual output}}{\text{effective capacity}}(100\%) = \frac{27}{20}(100\%) = 135\%$$

$$\text{Utilization}_{\text{design}} = \frac{\text{actual output}}{\text{design capacity}}(100\%) = \frac{27}{30}(100\%) = 90\%$$

The utilization rates show that the bakery's current output is only slightly below its design capacity and output is considerably higher than its effective capacity. The bakery can probably operate at this level for only a short time.

Capacity Considerations

We have seen that changing capacity is not as simple as acquiring the right amount of capacity to exactly match our needs. The reason is that capacity is purchased in discrete chunks. Also, capacity decisions are long term and strategic in nature. Acquiring

anticipated capacity ahead of time can save cost and disruption in the long run. Later, when demand increases, output can be increased without incurring additional fixed cost. Extra capacity can also serve to intimidate and preempt competitors from entering the market. Important implications of capacity that a company needs to consider when changing its capacity are discussed in this section.

▶ **Best operating level** The volume of output that results in the lowest average unit cost.

▶ **Economies of scale** A condition in which the average cost of a unit produced is reduced as the amount of output is increased.

▶ **Diseconomies of scale** A condition in which the cost of each additional unit made increases.

Economies of Scale Every production facility has a volume of output that results in the lowest average unit cost. This is called the facility's **best operating level**. Figure 9-1 illustrates how the average unit cost of output is affected by the volume produced. You can see that as the number of units produced is increased, the average cost per unit drops. The reason is that when a large amount of goods is produced, the costs of production are spread over that large volume. These costs include the fixed costs of buildings and facilities, the costs of materials, and processing costs. The more units are produced, the larger the number of units over which costs can be spread—that is, the greater the **economies of scale**. The concept of economies of scale is very well known. It basically states that the average cost of a unit produced is reduced when the amount of output is increased.

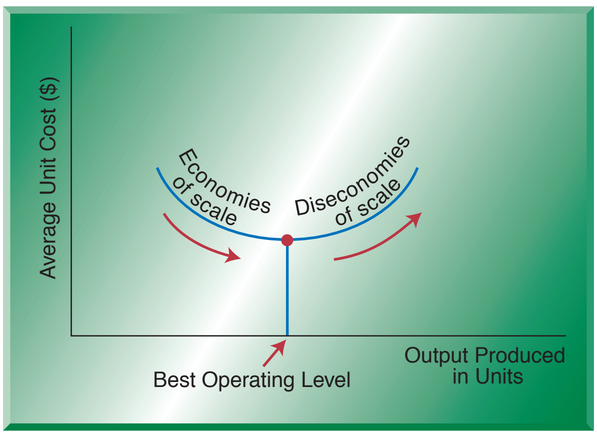
You use the concept of economies of scale in your daily life, whether or not you are aware of it. Suppose you decide to make cookies in your kitchen. Think about the cost per cookie if you make only five cookies. There would be a great deal of effort—getting the ingredients, mixing the dough, shaping the cookies—all for only five cookies. If you had everything set up, making five additional cookies would not cost much more. Perhaps making even ten more cookies would cost only slightly more because you had already set up all the materials. This lower cost is due to economies of scale.

Diseconomies of Scale What if you continued to increase the number of cookies you chose to produce? For a while, making a few more cookies would not require much additional effort. However, after a certain point there would be so much material that the kitchen would become congested. You might have to get someone to help because there was more work than one person could handle. You might have to make cookies longer than expected, and the cleanup job might be much more difficult. You would be experiencing **diseconomies of scale**. Diseconomies of scale occur at a point beyond the best operating level, when the cost of each additional unit made increases. Diseconomies of scale are also illustrated in Figure 9-1.

Operating a facility close to its best operating level is clearly important because of the impact on costs. However, we have to keep in mind that different facility sizes have different best operating levels. In our cookie example, we can see that the number of

FIGURE 9-1

Different operating levels of a facility



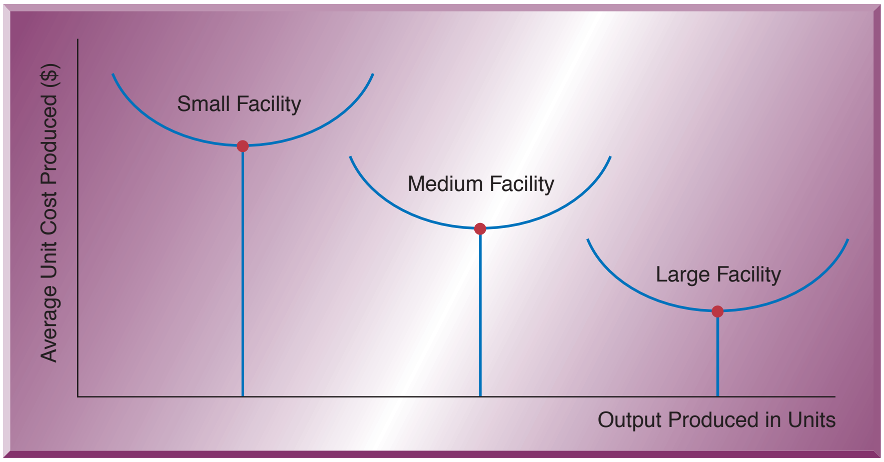


FIGURE 9-2

Best operating levels as functions of facility size

cookies comfortably produced by one person in a small kitchen would be much lower than the number produced by three friends in a large kitchen. Figure 9-2 shows how best operating level varies between facilities of different sizes.

You can see that each facility experiences both economies and diseconomies of scale. However, their best operating levels are different. This is a very important consideration when changing capacity levels. The capacity of a business can be changed by either expanding or reducing the amount of capacity. Although both decisions are important, expansion is typically a costlier and more critical event.

When expanding capacity, management has to choose between one of the following two alternatives:

Alternative 1: Purchase one large facility, requiring one large initial investment.
Alternative 2: Add capacity incrementally in smaller chunks as needed.

The first alternative means that we would have a large amount of excess capacity in the beginning and that our initial costs would be high. We would also run the risk that demand might not materialize and we would be left with unused overcapacity. On the other hand, this alternative allows us to be prepared for higher demand in the future. Our best operating level is much higher with this alternative, enabling us to operate more efficiently when meeting higher demand. Our costs would be lower in the long run, since one large construction project typically costs more than many smaller construction projects due to startup costs. Thus, alternative 1 provides greater rewards but is more risky. Alternative 2 is less risky but does not offer the same opportunities and flexibility. It is up to management to weigh the risks versus the rewards in selecting an alternative.

Focused Factories Facilities can respond more efficiently to demand if they are small, specialized, and focused on a narrow set of objectives; this concept is referred to as **focused factories**. We encountered this concept in Chapter 7 when we studied just-in-time (JIT) systems. Focused factories are only one of many factors that contribute to the success of JIT, but the concept is applicable to any facility.

▶ **Focused factories** Facilities that are small, specialized, and focused on a narrow set of objectives.

The idea that large facilities are necessary for success because they bring economies of scale is rather dated. Today's facilities must succeed in a business environment that has short product and technology life cycles and in which flexibility is more important than ever before. Large facilities tend to be less flexible because they generally contain larger machines or process technology that is costly to change in order to make other goods and services. Many companies have realized that to be more agile they need to

be focused. A smaller, specialized facility can be more efficient because it can focus on a smaller number of tasks and fewer goals.

MKT

Even a large facility can benefit from the concept of the focused factory by creating what is known as a *plant within a plant*, or PWP. A PWP is a large facility divided into smaller, more specialized facilities that have separate operations, competitive priorities, technology, and workforce. They can be physically separated with a wall or barrier and kept independent from one another. In this manner, unnecessary layers of bureaucracy are eliminated, and each "plant" is free to focus on its own objectives. PWP was discussed in detail in Chapter 3.

LINKS TO PRACTICE

Focus in the Retail Industry

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Recent trends in the retail industry provide an excellent example of factory focus. In the 1980s, retail sales were dominated by large department stores such as Sears, JC Penney's, and Federated Department Stores. However, in the 1990s, gains in sales were made by specialty stores such as the Gap, The Limited, and Ann Taylor, while large department stores faltered. The reason is that consumer preferences change very rapidly, and each small specialty store can focus precisely on the needs of its customer group. Specialty stores are able to focus on a specific set of customers and respond to their unique needs. The Limited and the Gap are excellent examples of factory focus, with specialty stores such as Limited Too, Baby Gap, and Gap Kids.

Subcontractor Networks Another alternative to having a large production facility is to develop a large network of subcontractors and suppliers who perform a number of tasks. This is one of the fastest-growing trends today. Companies are realizing that to be successful in today's market, they need to focus on their core capabilities—for example, by hiring third parties or subcontractors to take over tasks that the company does not need to perform itself. Companies such as American Airlines and Procter & Gamble have hired outside firms to manage noncritical inventories. Also, many companies are contracting with suppliers to perform tasks that they used to perform themselves. A good example is in the area of quality management. Historically, companies performed quality checks on goods received from suppliers. Today, suppliers and manufacturers work together to achieve the same quality standards, and much of the quality checking of incoming materials is performed at the supplier's site. Another example can be seen in the auto industry, where manufacturers are placing more responsibility on suppliers to perform tasks such as design of packaging and transportation of goods. By placing more responsibility on subcontractors and suppliers, a manufacturer can focus on tasks that are critical to its success, such as product development and design.

MAKING CAPACITY PLANNING DECISIONS

The three-step procedure for making capacity planning decisions is as follows:

Step 1 Identify Capacity Requirements The first step is to identify the levels of capacity needed by the company now, as well as in the future. A company cannot decide whether to purchase a new facility without knowing exactly how much capacity it will need in the future. It also needs to identify the gap between available capacity and future requirements.

Step 2 Develop Capacity Alternatives Once capacity requirements have been identified, the company needs to develop a set of alternatives that would enable it to meet future capacity needs.

Step 3 Evaluate Capacity Alternatives The last step in the procedure is to evaluate the capacity alternatives and select the one alternative that will best meet the company's requirements.

Let's look at these steps in a little more detail.

Identify Capacity Requirements

Long-term capacity requirements are identified on the basis of forecasts of future demand. Certainly, companies look for long-term patterns such as trends when making forecasts. However, long-term patterns are not enough at this stage. Planning, building, and starting up a new facility can take well over five years. Much can happen during that time. When the facilities are operational, they are expected to be utilized for many years into the future. During this time frame numerous changes can occur in the economy, consumer base, competition, technology, and demographic factors, as well as in government regulation and political events.

Forecasting Capacity Capacity requirements are identified on the basis of forecasts of future demand. Forecasting at this level is performed using qualitative forecasting methods, some of which are discussed in Chapter 8. Qualitative forecasting methods, such as *executive opinion* and the *Delphi method*, use subjective opinions of experts. These experts may consider inputs from quantitative forecasting models that can numerically compute patterns such as trends. However, because so many variables can influence demand at this level, the experts use their judgment to validate the quantitative forecast or modify it based on their own knowledge.

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One way to proceed with long-range demand forecasting at this stage is to first forecast overall market demand. For example, experts might forecast the total market for overnight delivery to be $30 billion in five years. Then the company can estimate its market share as a percentage of the total. For example, our market share may be 15 percent. From that we can compute an estimate of demand for our company in five years by multiplying the overall market demand with the percentage held by our company (0.15 × $30 billion = $4.5 billion). That forecast of demand can then be translated into specific facility requirements.

Capacity Cushions Companies often add **capacity cushions** to their regular capacity requirements. A capacity cushion is an amount of capacity added to the needed capacity in order to provide greater flexibility. Capacity cushions can be helpful if demand is greater than expected. Also, cushions can help the ability of a business to respond to customer needs for different products or different volumes. Finally, businesses that operate too close to their maximum capacity experience many costs due to diseconomies of scale and may also experience deteriorating quality.

▶ **Capacity cushion**
Additional capacity added to regular capacity requirements to provide greater flexibility.

MKT

Strategic Implications Finally, a company needs to consider how much capacity its competitors are likely to have. Capacity is a strategic decision, and the position of a company in the market relative to its competitors is very much determined by its capacity. At the same time, plans by all major competitors to increase capacity may signal the potential for overcapacity in the industry. Therefore, the decision as to how much capacity to add should be made carefully.

Large expansion alternatives often involve construction of new facilities.

Richard Braine/Stone/Getty Images

Develop Capacity Alternatives

Once a company has identified its capacity requirements for the future, the next step is to develop alternative ways to modify its capacity. One alternative is to do nothing and reevaluate the situation in the future. With this alternative, the company would not be able to meet any demands that exceed current capacity levels. Choosing this alternative and the time to reevaluate the company's needs is a strategic decision. The other alternatives require deciding whether to purchase one large facility now or add capacity incrementally, as discussed earlier in the chapter.

Capacity Alternatives:
1. Do nothing
2. Expand large now
3. Expand small now, with option to add later

Evaluate Capacity Alternatives

There are a number of tools that we can use to evaluate our capacity alternatives. Recall that these tools are only decision-support aids. Ultimately, managers have to use many different inputs, as well as their judgment, in making the final decision. One of the most popular of these tools is the decision tree. In the next section we look more closely at how decision trees can be helpful to managers at this stage.

DECISION TREES

Decision trees are useful whenever we have to evaluate interdependent decisions that must be made in sequence and when there is uncertainty about events. For that reason, they are especially useful for evaluating capacity expansion alternatives given that future demand is uncertain. Remember that our main decision is whether to purchase a large facility or a small one with the possibility of expansion later. You can see that the decision to expand later is dependent on choosing a small facility now. Which

alternative ends up being best will depend on whether demand turns out to be high or low. Unfortunately, we can only forecast future demand and have to incur some risks.

A **decision tree** is a diagram that models the alternatives being considered and the possible outcomes. Decision trees help by giving structure to a series of decisions and providing an objective way of evaluating alternatives. Decision trees contain the following information:

▶ **Decision tree** Modeling tool used to evaluate independent decisions that must be made in sequence.

- *Decision points.* These are the points in time when decisions, such as whether or not to expand, are made. They are represented by squares, called "nodes."
- *Decision alternatives.* Buying a large facility and buying a small facility are two decision alternatives. They are represented by "branches" or arrows leaving a decision point.
- *Chance events.* These are events that could affect the value of a decision. For example, demand could be high or low. Each chance event has a probability or likelihood of occurring. For example, there may be a 60 percent chance of high demand and a 40 percent chance of low demand. Remember that the sum of the probabilities of all chances must add up to 100 percent. Chance events are "branches" or arrows leaving circular nodes.
- *Outcomes.* For each possible alternative an outcome is listed. In our example, that may be expected profit for each alternative (expand now or later) given each chance event (high demand or low demand).

These diagrams are called decision trees because the diagram of the decisions resembles a tree. Simple decision trees are not hard to understand. Next we look at an example to see how a decision tree might be used to solve a capacity alternative problem.

EXAMPLE 9.2

Using Decision Trees

Anna, the owner of Anna's Greek Restaurant, has determined that she needs to expand her facility. The decision is whether to expand now with a large facility, incurring additional costs and taking the risk that demand will not materialize, or expand now on a smaller scale, knowing that she will have to consider expanding again in three years. She has estimated the following chances for demand:

- The likelihood of demand being high is 0.70.
- The likelihood of demand being low is 0.30.

She has also estimated profits for each alternative:

- Large expansion has an estimated profitability of either $300,000 or $50,000, depending on whether demand turns out to be high or low.
- Small expansion has a profitability of $80,000, assuming that demand is low.
- Small expansion with an occurrence of high demand would require considering whether to expand further. If she expands at that point, her profitability is expected to be $200,000. If she does not expand further, profitability is expected to be $150,000.

Next we develop a decision tree to solve Anna's problem.

- **Before You Begin:** Remember that before you begin a decision tree problem, you should first draw a decision tree diagram. Then add the given information to the diagram and proceed to evaluate it.

- **Solution:**
To solve this problem we first need to draw the decision tree. Table 9-2 shows steps in drawing a decision tree.

TABLE 9-2

Procedure for Drawing a Decision Tree

1. Draw a decision tree from left to right. Use squares to indicate decisions and circles to indicate chance events.
2. Write the probability of each chance event in parentheses.
3. Write out the outcome for each alternative in the right margin.

A decision tree is shown in Figure 9-3. We read the diagram from left to right, with node 1 representing the first decision point. The two alternatives at that decision point are presented as branches. They are labeled with the two alternatives "Expand Small" and "Expand Large." Regardless of which alternative is followed, some chance events will take place. In our example the chance events are the occurrence of either high or low demand. The circular node represents the chance events, with the branches providing the label and the probability of the event. For example, the chance of high demand is 0.70 and the chance of low demand is 0.30.

If we start with a small expansion and high demand occurs, we will have to decide whether or not to expand further. This second decision point is represented by node 2. The dollar amounts at the end of each alternative are the estimated profits. Now that we have drawn the decision tree, let's see how we can solve it. The procedure for solving a decision tree is outlined in Table 9-3.

▶ **Expected value (*EV*)** A weighted average of chance events, where each chance event is given a probability of occurrence.

We drew the decision tree from left to right. To evaluate it, we work backward, from right to left, to determine the expected value. The **expected value (*EV*)** is a weighted average of the chance events, where each chance event is given a probability of occurrence. We start with the profitability of each alternative, working backward and selecting the most profitable alternative. For example, at node 2 we should decide to expand further, because the profits from that decision are higher ($200,000 versus $150,000). If we come to that point, that is the decision we should make. The expected value (*EV*)

FIGURE 9-3

Decision tree for Anna's restaurant

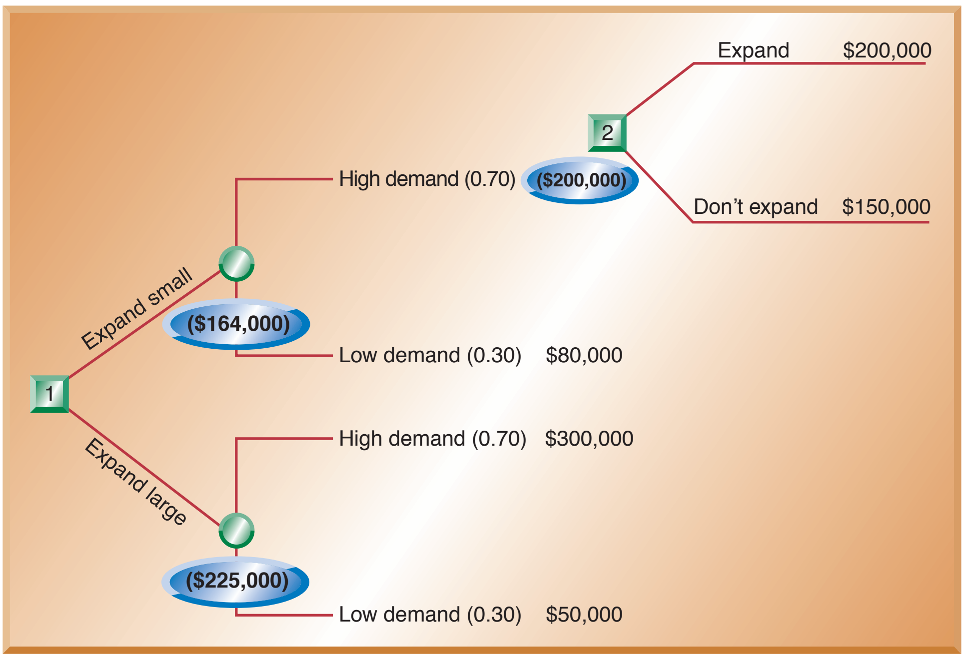


TABLE 9-3

Procedure for Solving a Decision Tree

1. To solve a decision tree, work from right to left. At each circle representing chance events, compute the expected value (*EV*).
2. Write the *EV*s below each circle.
3. Select the alternative with the highest *EV*.

of profits at that point is written below node 2. This is the expected value if we decide on a small expansion and high demand occurs.

To compute the expected value (*EV*) of the small expansion, we evaluate it as a weighted average of estimated profits given the probability of occurrence of each chance event:

$$EV_{\text{small expansion}} = 0.30(\$80{,}000) + 0.70(\$200{,}000) = \$164{,}000$$

$$EV_{\text{large expansion}} = 0.30(\$50{,}000) + 0.70(\$300{,}000) = \$225{,}000$$

The large expansion gives the higher expected value. This means that Anna should pursue a large expansion now.

Before You Go On

Up to this point we have focused exclusively on capacity planning. By now you should understand that capacity is the maximum output rate of a facility. Capacity is defined in different ways, depending on the nature of the business. You should understand the basic trade-off made in choosing between capacity planning alternatives and the procedure used to evaluate alternatives. Finally, make sure you understand the relationship between capacity planning and location analysis. In the next section we discuss location analysis, which is another decision area for operations managers. Note, however, that location analysis is usually made in conjunction with capacity planning. Because the size of a facility is typically tied to its location, these decisions are made together. Make sure you understand the relationship between these decisions and their strategic implications for the firm.

LOCATION ANALYSIS

▶ **Location analysis** Techniques for determining location decisions.

You might have heard the old real estate adage: the three most important factors in the value of a property are location, location, location. Have you ever left a service provider that you liked—say, a doctor, barber, or tailor—because they were in a location that was difficult to get to or too far away? Look at the business locations in your own neighborhood. We have all seen facilities in certain locations that have a high turnover of businesses and owners. The types of businesses and owners may be completely different, yet something about the location does not make it successful. Why do most fast-food restaurants locate near one another? In order to draw customers to one location. Why are the large automakers centered in Michigan? To draw suppliers to one area. Why do many medical facilities locate near hospitals? To be accessible to patients. Why do retail stores typically locate near each other? To attract a higher volume of customers.

These examples illustrate the strategic importance of location decisions. All other aspects of a business can be designed efficiently, but if the location is selected poorly, the business will have a harder time being successful. Different types of businesses emphasize different factors when making location decisions. Service organizations such as

restaurants, movie theaters, and banks focus on locating near their customers. Manufacturing organizations seek to be close to sources of transportation, suppliers, and abundant resources such as labor. However, many other factors need to be considered.

What Is Facility Location?

Facility location is determining the best geographic location for a company's facility. Facility location decisions are particularly important for two reasons. First, they require long-term commitments in buildings and facilities, which means that mistakes can be difficult to correct. Second, these decisions require sizable financial investment and can have a large impact on operating costs and revenues. Poor location can result in high transportation costs, inadequate supplies of raw materials and labor, loss of competitive advantage, and financial loss. Businesses therefore have to think long and hard about where to locate a new facility.

In most cases, there is no one best location for a facility. Rather, there are a number of acceptable locations. One location may satisfy some factors whereas another location may be better for others. If a new location is being considered in order to provide more capacity, the company needs to consider options such as expanding the current facility if the current location is satisfactory. Another option might be to add a new facility but also keep the current one. As you can see, there is a lot to consider.

Factors Affecting Location Decisions

Many factors can affect location decisions, including proximity to customers, transportation, source of labor, community attitude, proximity to suppliers, and many other factors. The nature of the firm's business will determine which factors should dominate the location decision. As already mentioned, service and manufacturing firms will focus on different factors. Profit-making and nonprofit organizations will also focus on different factors. Profit-making firms tend to locate near the markets they serve, whereas nonprofit organizations generally focus on other criteria.

It is important to identify factors that have a critical impact on the company's strategic goals. For example, even though proximity to customers is typically a critical factor for service firms, if the firm provides an in-home service (say, carpet cleaning), this may not be a critical issue. Also, while profit-making firms might locate near the markets they serve, nonprofit firms might choose to be near their major benefactors. Managers should also eliminate factors that are satisfied by every location alternative. Next we look more closely at some factors that affect location decisions.

Proximity to Sources of Supply Many firms need to locate close to sources of supply. The reasons for this can vary. In some cases, the firm has no choice, such as in farming, forestry, or mining operations, where proximity to natural resources is necessary. In other cases, the location may be determined by the perishable nature of goods, such as in preparing and processing perishable food items. Dole Pineapple has its pineapple farm and plant in Hawaii for both these purposes. Similarly, Tropicana has its processing plant in Florida, near the orange-growing orchards.

Another reason to locate close to sources of supply is to avoid high transportation costs—for example, if a firm's raw materials are much bulkier and costlier to move than the finished product. Transporting the finished product outbound is less costly than transporting the raw materials inbound, and the firm should locate closer to the source of supply. A paper mill is an example. Transporting lumber would be much more costly than transporting the paper produced.

LINKS TO PRACTICE

Locating in Silicon Valley

©AP/Wide World Photos

The importance of location decisions can be seen in the case of Internet companies during the boom of the dot-coms. Locating in Silicon Valley or San Francisco had become a major priority in the 1990s, for close proximity to highly skilled talent. Dot-coms were seeking over 4 million square feet of space in San Francisco, where only 1 million square feet was available. Consequently, the cost of locating there, including rent and leasing requirements, had become increasingly expensive. Tenants were paying $60 per square foot, an increase from the $40 per square foot paid just six months earlier. Landlords had also become picky about their tenants, and some were making unusual demands. Many were requiring as much as two years rent in advance. Others were even asking for equity in the company.

Then came the fall of the dot-coms. Space became abundant as many companies went out of business, and the cost of space dropped. Other companies, in an effort to remain financially viable, sought less costly locations. Almost overnight the importance of locating in Silicon Valley diminished.

Proximity to Customers Locating near the market they serve is often critical for many organizations, particularly service firms. To capture their share of the business, service firms need to be accessible to their customers. For this reason, service firms typically locate in high-population areas that offer convenient access. Examples include retail stores, fast-food restaurants, gas stations, grocery stores, dry cleaners, and flower shops. Large retail firms often locate in a central area of the market they serve. Smaller service firms usually follow the larger retailers because of the large number of the customers they attract. The smaller firms can usually count on getting some of the business.

Other reasons for locating close to customers may include the perishable nature of the company's products or high costs of transportation to the customer site. Food items such as groceries and baked goods, fresh flowers, and medications are perishable and need to be offered close to the market. Also, items such as heavy metal sheets, pipes, and cement need to be produced close to the market because the costs of transporting these materials are high.

Proximity to Source of Labor Proximity to an ample supply of qualified labor is important in many businesses, especially those that are labor intensive. The company needs to consider the availability of a particular type of labor and whether special skills are required. Some companies, such as those looking for assembly-line workers, want to be near a supply of blue-collar labor. Other companies may be looking for computer or technical skills and should consider locating in areas with a concentration of those types of workers.

Other factors that should be considered are local wage rates, the presence of local unions, and attitudes of local workers. Work ethics and attitudes toward work can vary greatly in different parts of the country and between urban and rural workers. Attitudes toward factors such as absenteeism, tardiness, and turnover can greatly affect a company's productivity.

Community Considerations The success of a company at a particular location can be affected by the extent to which it is accepted by the local community. Many communities welcome new businesses, viewing them as providing sources of tax revenues and opportunities for jobs, and as contributing to the overall well-being of the community. However, communities do not want businesses that bring pollution, noise, and traffic and that lower the quality of life. Extreme examples are a nuclear facility, a trash dump site, and an airport. Less extreme examples are companies like Wal-Mart, which often are not accepted by smaller communities, which may view such large merchants as a threat to their way of life and thus actively work to discourage them from locating there.

Site Considerations Site considerations for a particular location include factors such as utility costs, taxes, zoning restrictions, soil conditions, and even climate. These factors are not too different from those one would consider when purchasing a home or a lot to build on. Just as most homeowners consider their purchase to be an investment, so does a business. Inspectors should be hired to perform a thorough evaluation of the grounds, such as checking for adequate drainage. Site-related factors can also limit access roads for trucks and make it difficult for customers to reach the site.

Quality-of-Life Issues Another important factor in location decisions is the quality of life a particular location offers the company's employees. This factor can also become important in the future when the business is recruiting high-caliber employees. Quality of life includes factors such as climate, a desirable lifestyle, good schools, and a low crime rate. Certainly, quality of life would not be considered the most critical factor in selecting a location. However, when other factors do not differ much from one location to another, quality of life can be the decisive factor.

Other Considerations In addition to the factors discussed so far, there are others that companies need to consider. They include room for customer parking, visibility, customer and transportation access, as well as room for expansion. Room for expansion may be particularly important if the company has decided to expand now and possibly expand further at a later date. Other factors include construction costs, insurance, local competition, local traffic and road congestion, and local ordinances.

Globalization

► **Globalization**
The process of locating facilities around the world.

In addition to considering the specific factors affecting site location in the United States, companies need to consider how they will be affected by a major trend in business today: globalization. **Globalization** is the process of locating facilities around the world. Over the past decade it has become not only a trend but a matter-of-fact way of conducting business. Technology such as faxes, e-mails, video conferencing, and overnight delivery have made distance less relevant than ever before. Markets and competition are increasingly global. To compete effectively based on cost, many companies have had to expand their operations to include global sources of supply. Factors other than mere distance have become critical in selecting a geographic location.

Deciding to expand an operation globally is not a simple decision. There are many things to consider, and the problems must be weighed along with the benefits. In this section we look at both advantages and disadvantages of global operations. We also look at some additional implications of global operations that managers need to consider.

Advantages of Globalization There are many reasons why companies choose to expand their operations globally. The main one, however, is to take advantage of foreign markets. The demand for imported goods has grown tremendously, and these markets offer a new arena for competition. Also, locating production facilities in foreign countries reduces the stigma associated with buying imports. This concept works not only for U.S. companies abroad but for foreign companies in the United States as well. For example, Japanese automobile manufacturers have located in the United States and employed American workers, which has gone a long way toward eliminating negative attitudes about buying Japanese cars. Being in the United States has also reduced their exposure to currency variations between the dollar and yen.

Another advantage of global locations is reduction of trade barriers. By producing goods in the country where customers are located, a company can avoid import quotas. Trade barriers have also been reduced through the creation of trading blocs such as the European Union and trade agreements such as NAFTA (North American Free Trade Agreement). We discussed the contribution of these agreements to globalization in Chapter 1.

Cheap labor in countries such as Korea, Taiwan, and China has also attracted firms to locate there. Often it is cheaper to send raw materials to these countries for fabrication and assembly and then ship them elsewhere for final consumption than it is to keep the process in this country. The cost of labor can be so low that it more than offsets the additional transportation costs.

An area that has further encouraged globalization is the growth of just-in-time manufacturing, which encourages suppliers and manufacturers to be in close proximity to one another. Many suppliers have moved closer to the manufacturers they supply, and some manufacturers have moved closer to their suppliers.

Disadvantages of Globalization Although there are advantages to globalization, there are also a number of disadvantages that companies should consider. Political risks can be large, particularly in countries with unstable governments. For example, during a period of political unrest a company may have its technology confiscated. Foreign governments may also impose restrictions, tariffs on particular industries, and local ordinances that must be obeyed.

Using offshore suppliers might mean that a company may need to share some of its proprietary technology. Today's age of total quality management encourages the sharing of this type of information between manufacturers and suppliers to the advantage of both parties. A manufacturer may want to think carefully before sharing, however.

Another issue is whether to use local employees. Companies are often attracted to cheap foreign labor. However, the company might find that worker attitudes toward tardiness and absenteeism are different. Also, worker skills and productivity may be considerably lower, offsetting the benefits of lower wages.

The local infrastructure is another important issue. Many foreign countries do not have the developed infrastructure necessary for companies to operate in the manner that they do in their home country. Infrastructure includes everything from roads to utilities as well as other support services.

Issues to Consider in Locating Globally Firms are attracted to foreign locations in order to take advantage of foreign markets; cheaper suppliers or labor; and natural resources such as copper, aluminum, and timber. However, there are many issues to

consider when locating globally. One such issue is the effect of a *different culture*. Each culture has a different set of values, norms, ethics, and standards. For example, in France it is considered polite to be slightly late for an appointment, and such lateness is quite customary. The British, on the other hand, consider punctuality highly important and tardiness very rude. You can see how misunderstandings can develop even through simple differences like this one.

Language barriers are another potential problem. Employees need to be able to communicate easily in their work environment. Engaging in discussions, following instructions, and understanding exactly what is being said can become difficult when employees speak different languages. Even when one language is translated into another, the translation may have lost very essential parts of the meaning, resulting in damaging misunderstanding.

Different laws and regulations—including everything from pollution regulations to labor laws—may require changes in business practices. Also, what is acceptable in one culture may be completely unacceptable or even illegal in another. For example, in some countries offering a bribe may be an acceptable part of doing business, whereas in others it may land a person in jail.

Although it is important to know the factors affecting facility location, it is not enough for making good location decisions. In the next section we look at specific tools that can help managers with facility location decisions.

MAKING LOCATION DECISIONS

Procedure for Making Location Decisions

As with capacity planning, managers need to follow a three-step procedure when making facility location decisions. These steps are as follows:

Step 1 Identify Dominant Location Factors. In this step managers identify the location factors that are dominant for the business. This requires managerial judgment and knowledge.

Step 2 Develop Location Alternatives. Once managers know what factors are dominant, they can identify location alternatives that satisfy the selected factors.

Step 3 Evaluate Location Alternatives. After a set of location alternatives have been identified, managers evaluate them and make a final selection. This is not easy because one location may be preferred based on one set of factors, whereas another may be better based on a second set of factors.

Procedures for Evaluating Location Alternatives

A number of procedures can help in evaluating location alternatives. These are decision-support tools that help structure the decision-making process. Some of them help with qualitative factors that are subjective, such as quality of life. Others help with quantitative factors that can be measured, such as distance. A manager may choose to use multiple procedures to evaluate alternatives and come up with a final decision. Remember that the location decision is one that a company will have to live with for a long time. It is highly important that managers make the right decision.

Factor Rating You have seen by now that many of the factors that managers need to consider when evaluating location alternatives are qualitative in nature. Their importance is also highly subjective, based on the opinion of who is evaluating them. An

excellent procedure that can be used to give structure to this process is called factor rating. **Factor rating** can be used to evaluate multiple alternatives based on a number of selected factors. It is valuable because it helps decision makers structure their opinions relative to the factors identified as important. The following steps are used to develop a factor rating:

▶ **Factor rating**
A procedure that can be used to evaluate multiple alternative locations based on a number of selected factors.

Step 1 Identify dominant factors (e.g., proximity to market, access, competition, quality of life).

Step 2 Assign weights to factors reflecting the importance of each factor relative to the other factors. The sum of these weights must be 100.

Step 3 Select a scale by which to evaluate each location relative to each factor. A commonly used scale is a five-point scale, with 1 being poor and 5 excellent.

Step 4 Evaluate each alternative relative to each factor, using the scale selected in Step 3. For example, if you chose to use a five-point scale, a location that was excellent based on quality of life might get a 5 for that factor.

Step 5 For each factor and each location, multiply the weight of the factor by the score for that factor and sum the results for each alternative. This will give you a score for each alternative based on how you have rated the factors and how you have weighted each of the factors at each location.

Step 6 Select the alternative with the highest score.

Let's look at an example to see how this procedure is used.

Using Factor Rating — EXAMPLE 9.3

Antonio is evaluating three different locations for his new Italian restaurant. Costs are comparable at all three locations. He has identified seven factors that he considers important and has decided to use factor rating to evaluate his three location alternatives based on a five-point scale, with 1 being poor and 5 excellent. Table 9-4 shows Antonio's factors, the weights he has assigned to each factor, as well as the factor score for each factor at each location.

Table 9-4 Factor Rating for Antonio's Italian Restaurant

		Factor Score at Each Location			Weighted Score for Each Location (Factor Weight × Factor Score)		
Factor	**Factor Weight**	**Location 1**	**Location 2**	**Location 3**	**Location 1**	**Location 2**	**Location 3**
Appearance	20	5	3	2	100	60	40
Ease of expansion	10	4	4	2	40	40	20
Proximity to market	20	2	3	5	40	60	100
Customer parking	15	5	3	3	75	45	45
Access	15	5	2	3	75	30	45
Competition	10	2	4	5	20	40	50
Labor supply	10	3	3	4	30	30	40
Total	**100**				**380**	**305**	**340**

From Table 9-4 it is clear that Antonio considers facility appearance and proximity to market the two most important factors, because he has rated each of these with a 20. Other factors are slightly less important. Note that Antonio selected the factors first. Then he decided to weight them based on his perception of their importance. He then computed a factor score for each factor at each location. Looking at the factor scores he selected, it appears that location 1 is excellent based on appearance, parking, and access, but poor based on closeness to the market. Location 3 is just the opposite, being excellent based on closeness to the market but poor based on facility

appearance. Location 2 appears to be somewhere in the middle. To evaluate which location alternative is best, Antonio needed to multiply the factor weight by the factor score for each factor at each location and then sum them. The best location alternative is that with the highest factor rating score. In Antonio's case, it is location 1. This problem can also be solved with a spreadsheet as shown:

	A	B	C	D	E	F	G
1							
2	**Factor Rating for Antonio's Italian Restaurant**						
3							
4		**Factor Scores (1-5 scale)**					
5	**Factor**	**Location 1**	**Location 2**	**Location 3**	**Factor Weight**		
6	Appearance	5	3	2	20		
7	Ease of expansion	4	4	2	10		
8	Proximity to market	2	3	5	20		
9	Customer parking	5	3	3	15		
10	Access	5	2	3	15		
11	Competition	2	4	5	10		
12	Labor supply	3	3	4	10		
13				Total	100		
14							
15	**Compute Weighted Factor Scores and Overall Scores for Each Location**						
16		**Weighted Factor Scores**					
17	**Factor**	**Location 1**	**Location 2**	**Location 3**			
18	Appearance	100	60	40			
19	Ease of expansion	40	40	20			
20	Proximity to market	40	60	100			
21	Customer parking	75	45	45			
22	Access	75	30	45			
23	Competition	20	40	50			
24	Labor supply	30	30	40			
25	Totals	**380**	**305**	**340**			
26							
27	Best Total Score	**380**					
28	Best Location	**Location 1**					

E13: =SUM(E6:E12)

B18: =B6*$E6 (copied to B18:D24)

B25: =SUM(B18:B24) (copied right)

B27: =MAX(B25:D25)

B28: =INDEX(B17:D17,MATCH(B27,B25:D25,0))

▶ **Load–distance model** A procedure for evaluating location alternatives based on distance.

The Load–Distance Model The **load–distance model** is a procedure for evaluating location alternatives based on distance. The distance to be measured could be proximity to markets, proximity to suppliers or other resources, or proximity to any other facility that is considered important. The objective of the model is to select a location that minimizes the total amount of loads moved weighted by the distance traveled. What is a load? A load represents the goods moved in or out of a facility or the number of movements between facilities. For example, if 200 boxes of Kellogg's cereal are shipped between the local warehouse and a grocery store, that is the load between the warehouse and grocery store. The idea is to reduce the amount of distance between facilities that have a high load between them.

The model is shown in Table 9-5. Relative locations are compared by computing the load–distance, or *ld*, score for each location. The *ld* score for a particular location

TABLE 9-5

The Load–Distance Model

ld score for a location $= \Sigma\, l_{ij}d_{ij}$
where l_{ij} = load between locations i and j
d_{ij} = distance between locations i and j

is obtained by multiplying the load (denoted by l) for each location by the distance traveled (denoted by d) and then summing over all the locations. This score is a surrogate measure for movement of goods, material handling, or even communication. Our goal is to make the ld score as low as possible by reducing the distance the large loads have to travel.

Next we look at the steps in developing the load–distance model.

Step 1 Identify Distances. The first step is to identify the distances between location sites. It is certainly possible to use the actual mileage between locations. However, it is much quicker, and just as effective, to use simpler measures of distance. A frequently used measure of distance is **rectilinear distance**, the shortest distance between two points measured by using only north–south and east–west movements. To measure rectilinear distance, we place grid coordinates on a map and use them to measure the distance between two locations. Figure 9-4 presents an example of how the distance between locations A and B could be measured using rectilinear distance.

► **Rectilinear distance** The shortest distance between two points measured by using only north–south and east–west movements.

The rectilinear distance between two locations, A and B, is computed by summing the absolute differences between the x coordinates and the absolute differences between the y coordinates. The equation is as follows:

$$d_{AB} = |x_A - x_B| + |y_A - y_B|$$

In our example, the coordinates for location A are (30, 40). The coordinates for location B are (10, 15). Therefore, the rectilinear distance between these two points is

$$d_{AB} = |30 - 10| + |40 - 15| = 45 \text{ miles}$$

Step 2 Identify Loads. The next step is to identify the loads between different locations. The notation l_{ij} is used to indicate the load between locations i and j.

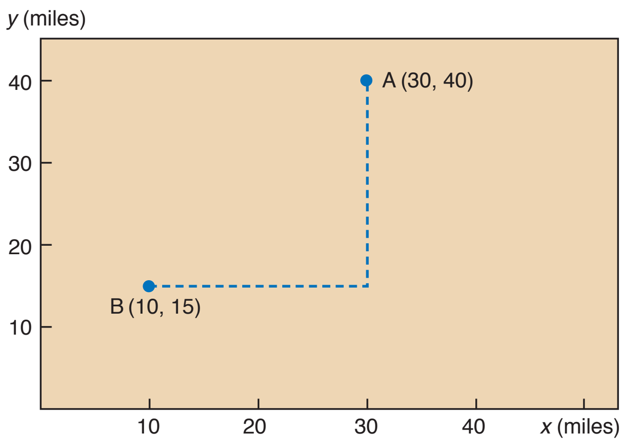


FIGURE 9-4

Rectilinear distance between points A and B

Step 3 Calculate the Load–Distance Score for Each Location. Next we calculate the load–distance score for each location by multiplying the load, l_{ij}, by the distance, d_{ij}. We compute the sum of $l_{ij}d_{ij}$ to get the *ld* score. Finally, we select the site with the lowest load–distance score.

Next we look at an example to see how to use the model.

EXAMPLE 9.4

Using the Load–Distance Model

Matrix Manufacturing Corporation is considering where to locate its warehouse in order to service its four stores located in four Ohio cities: Cleveland, Columbus, Cincinnati, and Dayton. Two possible sites for the warehouse are being considered. One is in Mansfield, Ohio, and the other is in Springfield, Ohio. Let's follow the steps of the load–distance model to select the best location for the warehouse.

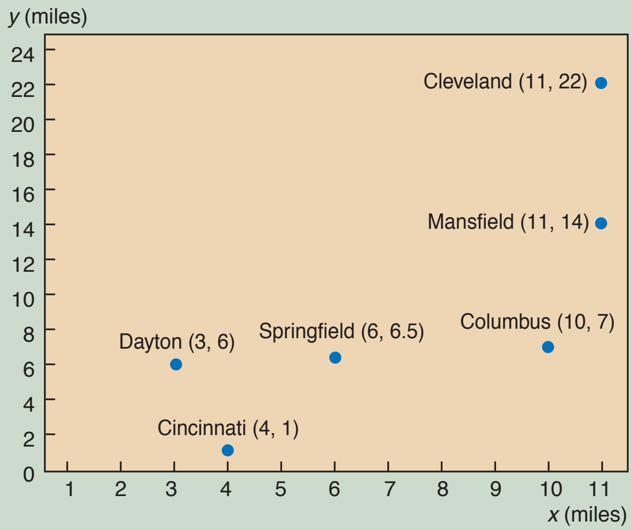
- **Before You Begin:** To solve this problem, follow the three steps given in the text for selecting a location with the load–distance model.

- **Solution:**

Step 1 Identify Distances. The distances between the locations can be seen in Figure 9-5, which shows a map of the cities with grid coordinates. The coordinates allow us to compute the distances between the cities. To compute the specific distances, we use the rectilinear distance measure.

FIGURE 9-5

Location map for Matrix Manufacturing



From Figure 9-5 we can compute the distances between the four cities and the Springfield site as follows:

City	Distance to Springfield
Cleveland	$\lvert 11-6\rvert + \lvert 22-6.5\rvert = 20.5$
Columbus	$\lvert 10-6\rvert + \lvert 7-6.5\rvert = 4.5$
Cincinnati	$\lvert 4-6\rvert + \lvert 1-6.5\rvert = 7.5$
Dayton	$\lvert 3-6\rvert + \lvert 6-6.5\rvert = 3.5$

Similarly, we can compute the distance between the four cities and the Mansfield site as follows:

City	Distance to Mansfield
Cleveland	$\|11 - 11\| + \|22 - 14\| = 8$
Columbus	$\|10 - 11\| + \|7 - 14\| = 8$
Cincinnati	$\|4 - 11\| + \|1 - 14\| = 20$
Dayton	$\|3 - 11\| + \|6 - 14\| = 16$

Step 2 Identify Loads. The next step is to identify the loads between the four cities and the warehouse. Remember that these loads will be the same regardless of where the warehouse is located. For this reason, we want to locate the warehouse at a place that will minimize the amount of distance large loads will have to travel.

City	Load between City and Warehouse
Cleveland	15
Columbus	10
Cincinnati	12
Dayton	4

Step 3 Calculate the Load–Distance Score for Each Location. The final step is to calculate the load–distance score for each location. The computation for Springfield is shown in Table 9-6.

Table 9-6 Computing the Load–Distance Score for Springfield

City	Load (l_{ij})	Distance (d_{ij})	$l_{ij}d_{ij}$
Cleveland	15	20.5	307.5
Columbus	10	4.5	45
Cincinnati	12	7.5	90
Dayton	4	3.5	14
Total		**Load–Distance Score: (456.5)**	

The load–distance score computed for Springfield does not tell us very much by itself. This number is useful only when comparing relative locations—that is, when we compare it to another load–distance score. The load–distance score for Mansfield is shown in Table 9-7.

Table 9-7 Computing the Load–Distance Score for Mansfield

City	Load (l_{ij})	Distance (d_{ij})	$l_{ij}d_{ij}$
Cleveland	15	8	120
Columbus	10	8	80
Cincinnati	12	20	240
Dayton	4	16	64
Total		**Load–Distance Score: (504)**	

The load–distance score for Mansfield is higher than the score for Springfield. Therefore, Matrix Manufacturing should locate its warehouse in Springfield. Note in the computation for the load–distance score for Mansfield that the load between the city and the warehouse did not change. What changed was the distance. Through the load–distance model we select a location that will minimize the distance large loads travel. This can also be computed using a spreadsheet, as shown.

	A	B	C	D	E	F	G	H	I
1									
2	**Load-Distance Model for Matrix Manufacturing**								
3									
4	**Coordinates of Stores (miles)**								
5		X	Y						
6	Cincinnati	4	1						
7	Cleveland	11	22						
8	Columbus	10	7						
9	Dayton	3	6						
10									
11	**Coordinates of Warehouses (miles)**								
12	Mansfield	11	14						
13	Springfield	6	6.5						
14									
15									
16	**Distances (rectilinear, in miles)**								
17		Cincinnati	Cleveland	Columbus	Dayton				
18	Mansfield	20	8	8	16				
19	Springfield	7.5	20.5	4.5	3.5				
20									
21	**Load between Warehouse and Store**								
22		Cincinnati	Cleveland	Columbus	Dayton				
23	Load	12	15	10	4				
24									
25	**Load-Distance Calculations**								
26		Cincinnati	Cleveland	Columbus	Dayton	Total			
27	Mansfield	240	120	80	64	**504**			
28	Springfield	90	307.5	45	14	**456.5**			
29									
30		Minimum Load-Di	**456.5**						
31		Best Location:	**Springfield**						

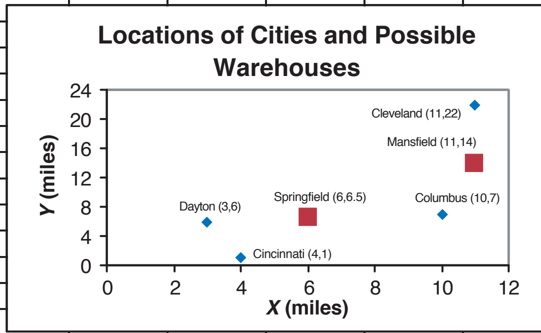
B18: =ABS($B12-$B$6)+ABS($C12-C6) (copied to B18:E19)

B27: =B$23*B18 (copied down and right)

F27: =SUM(B27:E27) (copied down)

C30: =MIN(F27:F28)

C31: =INDEX(A27:A28,MATCH(C30,F27:F28,0))



The Center of Gravity Approach When we used the load–distance model, we compared only two location alternatives. The load–distance was lower for Springfield than for Mansfield. However, we can also use the model to find other locations that may give an even lower load–distance score than Springfield. An easy way to do this is to start by testing the location at the center of gravity of the target area. The X and Y coordinates that give us the center of gravity for a particular area are computed in the following way:

$$X_{\text{c.g.}} = \frac{\sum l_i x_i}{\sum l_i}$$

$$Y_{\text{c.g.}} = \frac{\sum l_i y_i}{\sum l_i}$$

c.g. = center of gravity

The X coordinate for the center of gravity is computed by taking the X coordinate for each point and multiplying it by its load. These are then summed and divided by the sum of the loads. The same procedure is used to compute the Y coordinate.

The location identified with the center of gravity puts a larger penalty on long distances. This can have practical value given that longer distances impose more costs on the organization. However, the location identified may not be a feasible site because of geographic restrictions. For example, the center of gravity might turn out to be in the middle of Lake Michigan. However, the center of gravity provides an excellent starting point. We can use it to test the load–distance score of other locations in the area.

EXAMPLE 9.5

Computing the Center of Gravity

Find the center of gravity for the Matrix Manufacturing problem.

- **Before You Begin:** To solve this problem, use the center of gravity equations. Remember that you need to find both the *X* and *Y* coordinates.

- **Solution:**

Location	Coordinates (X, Y)	Load (l_i)	$l_i x_i$	$l_i y_i$
Cleveland	(11, 22)	15	165	330
Columbus	(10, 7)	10	100	70
Cincinnati	(4, 1)	12	48	12
Dayton	(3, 6)	4	12	24
Total		**41**	**325**	**436**

Now we need to find the coordinates for the center of gravity:

$$X_{\text{c.g.}} = \frac{\sum l_i x_i}{\sum l_i} = \frac{325}{41} = 7.9$$

$$Y_{\text{c.g.}} = \frac{\sum l_i y_i}{\sum l_i} = \frac{436}{41} = 10.6$$

Break-Even Analysis **Break-even analysis** is a technique used to compute the amount of goods that must be sold just to cover costs. The break-even point is precisely the quantity of goods a company needs to sell to break even. Whatever is sold above that point will bring a profit. Below that point the company will incur a loss. We discussed break-even analysis in Chapter 3 as a technique for evaluating the success of different products. In this chapter we use break-even analysis to evaluate different location alternatives. Remember that break-even analysis works with costs, such as fixed and variable costs. It can be an excellent technique when the factors under consideration can be expressed in terms of costs. Let's briefly review the basic break-even equations:

▶ **Break-even analysis**
Technique used to compute the amount of goods that must be sold just to cover costs.

$$\text{Total cost} = F + cQ$$

$$\text{Total revenue} = pQ$$

where F = fixed cost
c = variable cost per unit
Q = number of units sold
p = price per unit

At the break-even point, total cost and total revenue are equal. We can use those equations to solve for Q, which is the break-even quantity:

$$Q = \frac{F}{p - c}$$

As we saw in Chapter 3, these quantities can be obtained graphically. Now let's look at the basic steps in using break-even analysis for location selection.

Step 1: For Each Location, Determine Fixed and Variable Costs. Recall from Chapter 3 that fixed costs are incurred regardless of how many units are produced and include items such as overhead, taxes, and insurance. Variable costs are costs that vary directly with the number of units produced and include items such as materials and labor. Total cost is the sum of fixed and variable costs.

Step 2: Plot the Total Costs for Each Location on One Graph. To plot any straight line we need two points. One point is $Q = 0$, which is the y intercept. Another point can be selected arbitrarily, but it is best to use the expected volume of sales in the future.

Step 3: Identify Ranges of Output for Which Each Location Has the Lowest Total Cost.

Step 4: Solve Algebraically for the Break-Even Points over the Identified Ranges. Select the location that gives the lowest cost for the range of output required by the new facility.

EXAMPLE 9.6 Using Break-Even Analysis

Clean-Clothes Cleaners is a dry cleaning business that is considering four possible sites for its new operation. The annual fixed and variable costs for each site have been estimated as follows:

Location	Fixed Costs	Variable Costs
A	\$350,000	\$ 5/unit
B	\$170,000	\$25/unit
C	\$100,000	\$40/unit
D	\$250,000	\$20/unit

(a) Plot the total cost curves for each location on the same graph and identify the range of output for which each location provides the lowest total cost.
(b) If demand is expected to be 10,000 units per year, which is the best location?

- **Before You Begin:** To solve this problem, follow the four steps given in the text for using break-even analysis in location selection.

- **Solution:**

(a) Step 1 in the break-even procedure has already been completed; that is, we have identified the fixed and variable costs. The next step is to plot the total costs of each location on a graph. For each line that we have to plot, we need two points. The first point can be $Q = 0$. We can compute the second point using expected demand, which is $Q = 10{,}000$ units. For $Q = 10{,}000$ units we compute the following total costs for each location:

Location	Fixed Cost	Variable Cost	Total Cost
A	\$350,000	\$ 5 (10,000)	\$400,000
B	\$170,000	\$25 (10,000)	\$420,000
C	\$100,000	\$40 (10,000)	\$500,000
D	\$250,000	\$20 (10,000)	\$450,000

The plots of these graphs are shown in Figure 9-6. You can see that depending on the range of output, locations C, B, and A are best. Location D is never a best option.

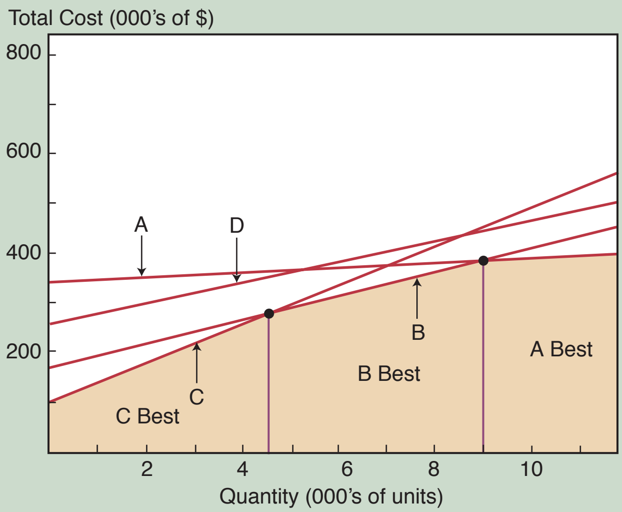


FIGURE 9-6

Break-even graph for Clean-Clothes Cleaners

(b) We can see the approximate ranges for each location in Figure 9-6. We can compute the exact ranges for each output location by finding the exact output level for which locations C and B are equal and for which locations B and A are equal. We can do this by computing the output levels at which the total cost equations for these locations are equal:

$$\text{Total cost equation for C} = \text{Total cost equation for B}$$

$$100{,}000 + \$40\,Q = 170{,}000 + \$25\,Q$$

$$Q = 4666.7 \text{ units}$$

Thus, the point between C and B is 4666.7, or roughly 4667 units.

$$\text{Total cost equation for B} = \text{Total cost equation for A}$$

$$170{,}000 + \$25\,Q = 350{,}000 + \$5\,Q$$

$$Q = 9000 \text{ units}$$

The breaking point between B and A is 9000 units, which means that location A would provide the lowest cost if we produce 9000 units or more. If we plan to meet a demand of 10,000 units, we should select location A. This problem can also be solved using a spreadsheet, as shown.

Break-Even Point Analysis for Clean Clothes Cleaners

Location	Fixed Cost	Variable Cost
A	$350,000	$5
B	$170,000	$25
C	$100,000	$40
D	$250,000	$20

Calculation of Exact Break-Even Point:

	Quantity
Between B and C	4,666.67
Between A and B	9,000.00

B12: =(B6-B7)/(C7-C6)

B13: =(B5-B6)/(C6-C5)

Enter any quantity

The Total Costs are computed, showing the best location for that quantity.

		Location	0
Quantity	4000		
Minimum Cost	$260,000	A	$370,000
Best Location	C	B	$270,000
		C	$260,000
		D	$330,000

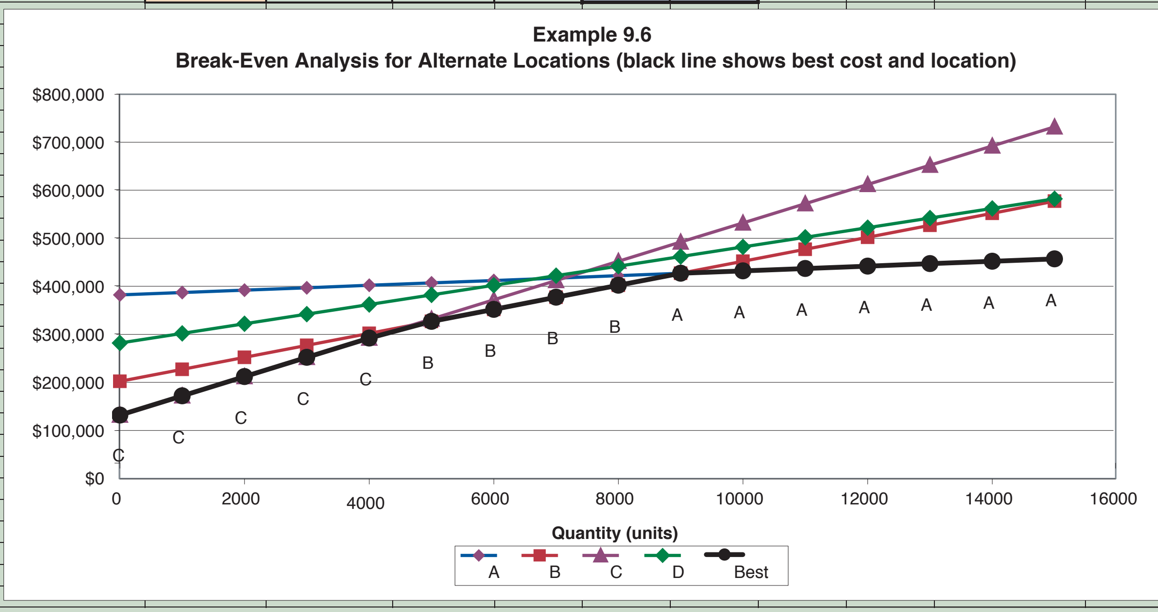
E18: =B5+C5*B$17 (copied down)

B18: =MIN(E18:E21)

B19: =INDEX(A5:A8,MATCH(B18,E18:E21,0))

Data Table to Compare Locations (highlighting shows best choice for each quantity)

Quantity	A	B	C	D	Best	Best Loc
	$370,000	$270,000	$260,000	$330,000	$260,000	C
0	$350,000	$170,000	$100,000	$250,000	$100,000	C
1000	$355,000	$195,000	$140,000	$270,000	$140,000	C
2000	$360,000	$220,000	$180,000	$290,000	$180,000	C
3000	$365,000	$245,000	$220,000	$310,000	$220,000	C
4000	$370,000	$270,000	$260,000	$330,000	$260,000	C
5000	$375,000	$295,000	$300,000	$350,000	$295,000	B
6000	$380,000	$320,000	$340,000	$370,000	$320,000	B
7000	$385,000	$345,000	$380,000	$390,000	$345,000	B
8000	$390,000	$370,000	$420,000	$410,000	$370,000	B
9000	$395,000	$395,000	$460,000	$430,000	$395,000	A
10000	$400,000	$420,000	$500,000	$450,000	$400,000	A
11000	$405,000	$445,000	$540,000	$470,000	$405,000	A
12000	$410,000	$470,000	$580,000	$490,000	$410,000	A
13000	$415,000	$495,000	$620,000	$510,000	$415,000	A
14000	$420,000	$520,000	$660,000	$530,000	$420,000	A
15000	$425,000	$545,000	$700,000	$550,000	$425,000	A



The Transportation Method The transportation method of linear programming is a useful technique for solving specific location problems; it is discussed in detail in the supplement for this text. The method relies on a specific algorithm to evaluate the cost impact of adding potential location sites to the network of existing facilities. For example, an existing network of facilities may consist of multiple sending and receiving sites. Our task might be to evaluate adding a new location site to this network, either a receiving site or a sending site. We might also wish to evaluate adding multiple new sites or completely redesigning the network. The transportation method can efficiently analyze all these situations and provide the lowest cost for each configuration considered.

CAPACITY PLANNING AND FACILITY LOCATION WITHIN OM: HOW IT ALL FITS TOGETHER

Decisions about capacity and location are highly dependent on forecasts of demand (Chapter 8). Forecasts determine the size of current and future capacity needs. Incorrect forecasts, where capacity is either over- or underestimated, can have a devastating effect on the capacity decision. Capacity is also affected by operations strategy (Chapter 2), as size of capacity is a key element of organizational structure. For example, the decision whether to expand now or later can be an important strategic choice. The former can preempt competition by enabling the company to be ready to meet demand. The latter can provide flexibility. Other operations decisions that are affected by capacity and location are issues of job design and labor skills (Chapter 11), choice on the mix of labor and technology, as well as choices on technology and automation (Chapter 3).

CAPACITY PLANNING AND FACILITY LOCATION ACROSS THE ORGANIZATION

By now it should be clear how capacity planning and location analysis affect operations management. However, these decisions are also important to many other functions in the company. In particular, finance and marketing have a great stake in capacity planning and location decisions.

FIN

Finance must be actively involved in the organization's capacity planning decisions. At the same time, operations managers need input from finance in order to finalize their capacity decisions. The reason should be clear. Capacity planning requires large financial expenditures. Building a large facility now would mean that funds would be tied up in excess capacity from which no financial return would be obtained for several years. At the same time, expanding capacity in increments could prove to be a greater financial drain due to poor planning. Location analysis, which is tied to the capacity planning decision, is basically a financial investment. Certain locations may be cheaper but may prove to be a poorer business investment. Finance needs to be an active participant in both the capacity planning and location analysis decisions.

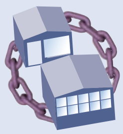
MKT

Marketing is another function that is highly affected by capacity planning and location decisions. The amount of current and future capacity restricts the ability to meet demand. Building a large facility that enables the company to capture future demand and position itself in the marketplace could be advantageous from a marketing perspective. On the other hand, given future demands and competition this may not be a critical issue. Marketing is the function that has this information. Also, locating near customers can be critical for certain businesses, particularly service organizations. Marketing managers are in the best position to understand which location factors are most important to customers.

Capacity planning and location analysis are excellent examples of decisions that must be made by operations, finance, and marketing working together. As you can see, each of these functional areas has its domain of expertise and provides information that the others do not have. Together, they must arrive at capacity and location decisions that are best for the company in the long run.

THE SUPPLY CHAIN LINK

Think of a supply chain as a pipeline that supplies a certain level of customer demand. In order for the pipeline to satisfy this demand, the pipeline must flow smoothly without disruption. This can only happen if capacity is uniform throughout the entire supply chain and is matched between entities. For example, a manufacturer must make sure that the capacity of its suppliers is sufficient to meet its own capacity needs and that there is no gap in product delivery.



The link to supply chains also ties to the location decision. Many firms locate close to their source of supply or require their suppliers to locate in close proximity to them. Recall that Dell requires its suppliers to be located within a 15-minute radius of its production facility. Without close proximity and a match in capacity between supply chain entities, smooth flow throughout the supply chain would not be possible.

Chapter Highlights

1. Capacity planning is deciding on the maximum output rate of a facility.
2. Location analysis is deciding on the best location for a facility.
3. Capacity planning and location analysis decisions are often made simultaneously because the location of a facility is usually related to its capacity. When a business decides to expand, it usually also addresses the issue of where to locate. These decisions are very important because they require long-term investments in buildings and facilities, as well as a sizable financial outlay. Also, if capacity planning and location analysis are not done properly, a business will not be able to meet customer demands or may find that it is losing customers due to lack of proximity to the market.
4. In both capacity planning and location analysis, managers must follow a three-step process to make a good decision. The steps are assessing needs, developing alternatives, and evaluating alternatives.
5. To choose between capacity planning alternatives managers may use decision trees, which are a modeling tool for evaluating independent decisions that must be made in sequence.
6. Key factors in location analysis include proximity to customers, transportation, source of labor, community attitude, and proximity to supplies. Service and manufacturing firms focus on different factors. Profit-making and nonprofit organizations also focus on different factors.
7. Several tools can be used to facilitate location analysis. Factor rating is a tool that helps managers evaluate qualitative factors. The load–distance model and center of gravity approach evaluate the location decision based on distance. Break-even analysis is used to evaluate location decisions based on cost values. The transportation method is an excellent tool for evaluating the cost impact of adding sites to the network of current facilities.

Key Terms

capacity 316
capacity planning 316
design capacity 318
effective capacity 319
capacity utilization 319
best operating level 320
economies of scale 320
diseconomies of scale 320
focused factories 321
capacity cushion 323
decision tree 325
expected value (*EV*) 326
location analysis 327
globalization 330
factor rating 333
load–distance model 334
rectilinear distance 335
break-even analysis 339

Formula Review

1. $ld = \Sigma\, l_{ij} d_{ij}$

2. $\text{Utilization}_{\text{effective}} = \dfrac{\text{actual output}}{\text{effective capacity}}(100\%)$

3. $\text{Utilization}_{\text{design}} = \dfrac{\text{actual output}}{\text{design capacity}}(100\%)$

4. $X_{\text{c.g.}} = \dfrac{\Sigma\, l_i x_i}{\Sigma\, l_i}$

   $Y_{\text{c.g.}} = \dfrac{\Sigma\, l_i y_i}{\Sigma\, l_i}$

5. $Q = \dfrac{F}{p - c}$

Solved Problems

(See student companion site for Excel template.)

• Problem 1

A manufacturer of ballet shoes has determined that its production facility has a design capacity of 300 shoes per week. The effective capacity, however, is 230 shoes per week. What is the manufacturer's capacity utilization relative to both design and effective capacity if output is 200 shoes per week?

• *Before You Begin:*

Remember that utilization is computed as the ratio of actual output over capacity. The difference between the two capacity measures is that one uses effective capacity and the other uses design capacity.

• *Solution*

$$\text{Utilization}_{\text{effective}} = \frac{\text{actual output}}{\text{effective capacity}}(100\%)$$

$$= \frac{200}{230}(100\%) = 86.9\%$$

$$\text{Utilization}_{\text{design}} = \frac{\text{actual output}}{\text{design capacity}}(100\%)$$

$$= \frac{200}{300}(100\%) = 66.7\%$$

The utilization rates computed show that the facility's current output is comfortably below its design capacity. It is also slightly below effective utilization, which means that the manufacturer is not using capacity to its fullest extent.

• Problem 2

EKG Software Development Corporation has determined that it needs to expand its current capacity. The decision has come down to whether to expand now with a large facility, incurring additional costs and taking the risk that the demand will not materialize, or to undertake a small expansion, knowing that the decision will have to be reconsidered in five years. Management has estimated the following chances for demand:

- The likelihood of demand being high is 0.60.
- The likelihood of demand being low is 0.40.

Profits for each alternative have been estimated:

- Large expansion has an estimated profitability of either \$1,000,000 or \$600,000, depending on whether demand turns out to be high or low.
- Small expansion has a profitability of \$500,000, assumming that demand is low.
- Small expansion with an occurrence of high demand would require considering whether to expand further. If the company expands at that point, the profitability is expected to be \$700,000. If it does not expand further, the profitability is expected to be \$500,000.

• *Before You Begin:*

Always begin a decision tree problem by drawing a decision tree diagram and adding the information that you are given. Then you can proceed to evaluate it.

• *Solution*

To solve this problem we need to draw the decision tree and evaluate it. A decision tree for this problem is shown in Figure 9-7. We read the diagram from left to right, with node 1 representing the first decision point: expanding with a large facility or expanding small. Following each decision are chance events, which are the occurrence of either high or low demand. The probabilities for each event are shown on each branch. Notice that decision point 2 is where we may have to make our second decision, but only if we expand small now and demand turns out to be high. Then in five years we would decide whether to expand further. The estimated profits are shown in the right margins. We can see that at node 2 we should decide to expand further because the profits from that decision are higher (\$700,000 versus \$500,000). The expected value (*EV*) of profits at that point is written below node 2. The dollar amounts at the end of each alternative are the estimated profits.

Now that we have drawn the decision tree, let's see how we can solve it. We do this by computing the expected value (EV) of the small and large expansions:

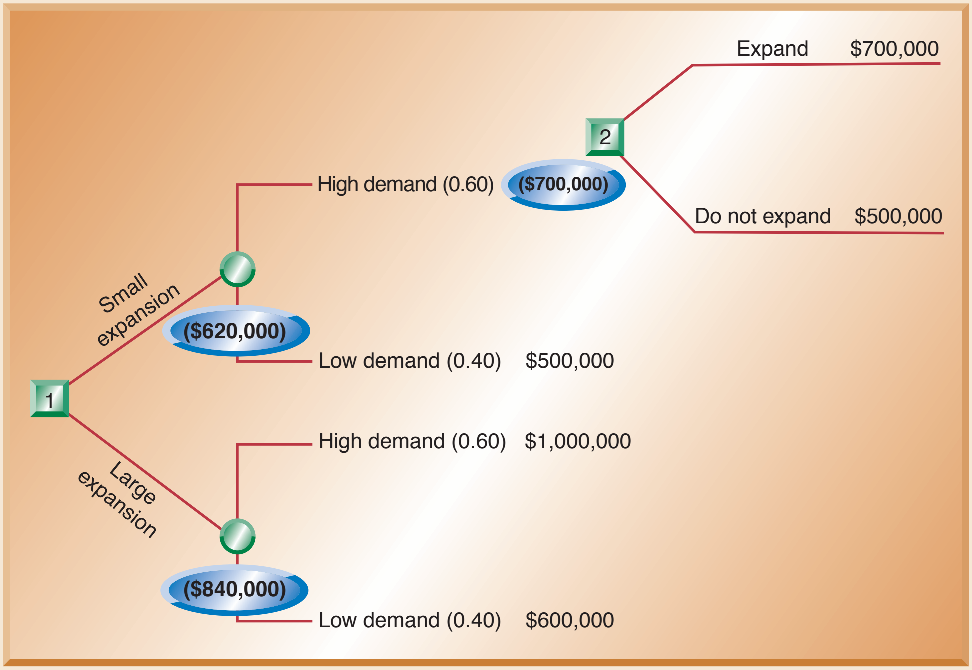
$$EV_{\text{small expansion}} = 0.60\ (\$700{,}000) + 0.40\ (\$500{,}000)$$
$$= \$620{,}000$$

$$EV_{\text{large expansion}} = 0.60\ (\$1{,}000{,}000) + 0.40\ (\$600{,}000)$$
$$= \$840{,}000$$

A large expansion now gives us a higher expected value.

FIGURE 9-7

Decision tree for EKG Corporation



• Problem 3

As a recent business school graduate, you are considering two job opportunities that both require relocation. The two jobs are identical and have the same career potential. Therefore, your decision will be based on an evaluation of the two locations. You have decided to use factor rating to make your decision and have identified the most important factors. You have also placed a weight on each factor that reflects its importance and have developed a factor score for each location based on a five-point scale. This information is shown in the table. Using the procedure for factor rating, complete the table.

• *Before You Begin:*

To solve this problem, for each location multiply the weight of the factor by the score for that factor and sum the results for each alternative. Then select the alternative with the highest score.

• *Solution*

The completed factor rating spreadsheet is shown on the next page.

Factor	Factor Weight	Factor Score at Each Location: Location 1	Location 2
Cost of living	10	5	2
Proximity to family	20	4	2
Climate	30	2	5
Transportation system	10	5	3
Quality of life	30	3	5

	A	B	C	D	E	F
1						
2	**Job Opportunity Location Analysis**					
3						
4		**Factor Scores (1-5 scale)**				
5	**Factor**	**Location 1**	**Location 2**	**Factor Weight**		
6	Cost of Living	5	2	10		
7	Proximity to Family	4	2	20		
8	Climate	2	5	30		
9	Transportation System	5	3	10		
10	Quality of Life	3	5	30		
11			Total	100		
12						
13	**Compute Weighted Factor Scores and Overall Scores for Each Location**					
14		**Weighted Factor Scores**				
15	**Factor**	**Location 1**	**Location 2**			
16	Cost of Living	50	20			
17	Proximity to Family	80	40			
18	Climate	60	150			
19	Transportation System	50	30			
20	Quality of Life	90	150			
21	Totals	**330**	**390**			
22						
23	Best Total Score	**390**				
24	Best Location	**Location 2**				

D11: =SUM(D6:D10)

B16: =B6*$D6
(copied to B16:C20)

B21: =SUM(B16:B20)
(copy right)

B23: =MAX(B21:C21)

B24: =INDEX(B15:C15,MATCH(B23,B21:C21,0))

Based on these results, you should move to location 2.

• Problem 4

Shoeless Joe is a specialty retailer that is deciding where to locate its new facility. The annual fixed and variable costs for each site under consideration have been estimated as follows:

Location	Fixed Costs	Variable Costs
A	\$70,000	\$1/unit
B	\$34,000	\$5/unit
C	\$20,000	\$8/unit
D	\$50,000	\$4/unit

If demand is expected to be 2000 units, which location is best?

• *Before You Begin:*

To solve this problem, you must first determine fixed and variable costs and add them to compute total cost. Then select the location with the lowest total cost.

• *Solution*

For $Q = 2000$ units, we compute the following total costs for each location:

Location	Fixed Cost	Variable Cost	Total Cost
A	\$70,000	\$1 (2000)	\$72,000
B	\$34,000	\$5 (2000)	\$44,000
C	\$20,000	\$8 (2000)	\$36,000
D	\$50,000	\$4 (2000)	\$58,000

Shoeless Joe should locate at location C because it provides the lowest total cost for the expected demand of 2000 units.

Discussion Questions

1. Explain why capacity planning is important to a business.
2. Explain the differences between design capacity and effective capacity.
3. How is capacity utilization computed, and what does it tell us?
4. What are the steps in capacity planning?
5. What are decision trees, and how do they help us make better decisions?
6. Find and discuss business examples of overcapacity and undercapacity.
7. Explain the consequences of poor location decisions for a business.
8. Find examples of good and bad location decisions.
9. Describe three advantages and three disadvantages of globalization.
10. Describe the steps used to make location decisions.
11. Describe five factors that should be considered in the location decision.
12. Explain the differences among factor rating, the load–distance model, and break-even analysis. What criteria does each method use to make the location decision?

Problems

1. Joe's Tasty Burger has determined that its production facility has a design capacity of 400 hamburgers per day. The effective capacity, however, is 250 hamburgers per day. Lately Joe has noticed that output has been 300 hamburgers per day. Compute both design and effective capacity utilization measures. What can you conclude?

2. A manufacturer of printed circuit boards has a design capacity of 1000 boards per day. The effective capacity, however, is 700 boards per day. Recently, the production facility has been producing 950 boards per day. Compute the design and effective capacity utilization measures. What do they tell you?

3. Beth's Bakery can comfortably produce 60 brownies in one day. If Beth takes some unusual measures, such as hiring her two aunts to help in the kitchen and work overtime, she can produce up to 100 brownies in one day.
   (a) What are the design and effective capacities for Beth's Bakery?
   (b) If Beth is currently producing 64 brownies, compute the capacity utilization for both measures. What can you conclude?

4. The town barber shop can accommodate 35 customers per day. The manager has determined that if two additional barbers are hired, the shop can accommodate 80 customers per day. What are the design and effective capacities for the barber shop?

5. The design and effective capacities for a local paper manufacturer are 1000 and 600 pounds of paper per day, respectively. At present, the manufacturer is producing 500 pounds per day. Compute capacity utilization for both measures. What can you conclude?

6. The design and effective capacities for a local emergency facility are 300 and 260 patients per day, respectively. Currently, the emergency room processes 250 patients per day. What can you conclude from these figures?

7. The Steiner-Wallace Corporation has determined that it needs to expand in order to accommodate growing demand for its laptop computers. The decision has come down to either expanding now with a large facility, incurring additional costs and taking the risk that the demand will not materialize, or expanding small, knowing that in three years management will need to reconsider the question.

   Management has estimated the following chances for demand:

   - The likelihood of demand being high is 0.60.
   - The likelihood of demand being low is 0.40.

   Profits for each alternative have been estimated as follows:

   - Large expansion has an estimated profitability of either $100,000 or $60,000, depending on whether demand turns out to be high or low.
   - Small expansion has a profitability of $50,000, assuming that demand is low.
   - Small expansion with an occurrence of high demand would require considering whether to expand further. If the company expands at that point, the profitability is expected to be $70,000. If it does not expand further, the profitability is expected to be $45,000.

   (a) Draw a decision tree showing the decisions, chance events, and their probabilities, as well as the profitability of outcomes.
   (b) Solve the decision tree and decide what Steiner-Wallace should do.

8. The owners of Sweet-Tooth Bakery have determined that they need to expand their facility in order to meet their increased demand for baked goods. The decision is whether to expand now with a large facility or expand small with the possibility of having to expand again in five years.

   The owners have estimated the following chances for demand:

   - The likelihood of demand being high is 0.70.
   - The likelihood of demand being low is 0.30.

Profits for each alternative have been estimated as follows:

- Large expansion has an estimated profitability of either \$80,000 or \$50,000, depending on whether demand turns out to be high or low.
- Small expansion has a profitability of \$40,000, assuming demand is low.
- Small expansion with an occurrence of high demand would require considering whether to expand further. If the bakery expands at this point, the profitability is to be \$50,000.

(a) Draw a decision tree showing the decisions, chance events, and their probabilities, as well as the profitability of outcomes.
(b) Solve the decision tree and decide what the bakery should do.

9. Demand has grown at Dairy May Farms, and it is considering expanding. One option is to expand by purchasing a very large farm that will be able to meet expected future demand. Another option is to expand the current facility by a small amount now and take a wait-and-see attitude, with the possibility of a larger expansion in two years.

Management has estimated the following chances for demand:

- The likelihood of demand being high is 0.70.
- The likelihood of demand being low is 0.30.

Profits for each alternative have been estimated as follows:

- Large expansion has an estimated profitability of either \$40,000 or \$20,000, depending on whether demand turns out to be high or low.
- Small expansion has a profitability of \$15,000, assuming that demand is low.
- Small expansion with an occurrence of high demand would require considering whether to expand further. If the company expands at that point, the profitability is expected to be \$35,000. If it does not expand further, the profitability is expected to be \$12,000.

(a) Draw a decision tree diagram for Dairy May Farms.
(b) Solve the decision tree you developed. What should Dairy May Farms do?

10. Spectrum Hair Salon is considering expanding its business, as it is experiencing a large growth. The question is whether it should expand with a bigger facility than needed, hoping that demand will catch up, or with a small facility, knowing that it will need to reconsider expanding in three years.

The management at Spectrum has estimated the following chances for demand:

- The likelihood of demand being high is 0.70.
- The likelihood of demand being low is 0.30.

Estimated profits for each alternative are as follows:

- Large expansion has an estimated profitability of either \$100,000 or \$70,000, depending on whether demand turns out to be high or low.
- Small expansion has a profitability of \$50,000, assuming that demand is low.
- Small expansion with an occurrence of high demand would require considering whether to expand further. If the business expands at this point, the profitability is expected to be \$90,000. If it does not expand further, the profitability is expected to be \$60,000.

Draw a decision tree and solve the problem. What should Spectrum do?

11. Jody of Jody's Custom Tailoring is considering expanding her growing business. The question is whether to expand with a bigger facility than she needs or with a small facility, knowing that she will have to reconsider expanding in three years.

Jody has estimated the following chances for demand:

- The likelihood of demand being high is 0.50.
- The likelihood of demand being low is 0.50.

She has also estimated profits for each alternative:

- Large expansion has an estimated profitability of either \$200,000 or \$100,000, depending on whether demand turns out to be high or low.
- Small expansion has a profitability of \$80,000, assuming that demand is low.
- Small expansion with an occurrence of high demand would require considering whether to expand further. If the business expands at that point, the profitability is expected to be \$120,000. If it does not expand further, the profitability is expected to be \$70,000.

Draw a decision tree and solve it. What should Jody's Custom Tailoring do?

12. The owners of Speedy Logistics, a company that provides overnight delivery of documents, are considering where to locate their new facility in the Midwest. They have narrowed their search down to two locations and have decided to use factor rating to make their decision. They have listed the factors they consider important and assigned a factor score to each location based on a five-point scale. The information is shown here. Using the procedure for factor rating, decide on the better location.

Factor	Factor Weight	Factor Score at Each Location: Location 1	Location 2
Proximity to airport	40	5	3
Proximity to road access	30	4	1
Proximity to labor source	10	3	5
Size of facility	20	2	4

13. Sue and Joe are a young married couple who are considering purchasing a new home. Their search has been reduced to two homes that they both like, at different locations. They have decided to use factor rating to help them make their decision. They have listed the factors they consider important and assigned a factor score to each location based on a five-point scale. The information is shown here. Using the procedure for factor rating, complete the table and help Sue and Joe make their decision.

Factor	Factor Weight	Factor Score at Each Location	
		Location 1	Location 2
Proximity to work	10	5	2
Proximity to family	20	4	2
Size of home	30	2	5
Transportation system	10	5	3
Neighborhood	30	3	5

14. The Bakers Dozen Restaurant is considering opening a new location. It has considered many factors and identified the ones that are most important. Two locations are being evaluated based on these factors, using factor rating. Each location has been evaluated relative to the factors on a five-point scale. These numbers are shown here. Use factor rating to help the restaurant decide on the better location.

Factor	Factor Weight	Factor Score at Each Location	
		Location 1	Location 2
Proximity to customers	30	5	2
Proximity to competition	10	4	2
Proximity to labor supply	30	2	5
Transportation system	20	5	3
Quality of life	10	3	5

15. Joe's Sports Supplies Corporation is considering where to locate its warehouse in order to service its four stores in four towns: A, B, C, and D. Two possible sites for the warehouse are being considered, one in Jasper and the other in Longboat. The following table shows the distances between the two locations being considered and the four store locations. Also shown are the loads between the warehouse and the four stores. Use the load–distance model to determine whether the warehouse should be located in Jasper or in Longboat.

Town	Distance to Jasper	Distance to Longboat	Load between City and Warehouse
A	30	12	15
B	6	12	10
C	10.5	30	12
D	4.5	24	8

16. Given here are the coordinates for each of the four towns to be serviced by the warehouse in Problem 15. Use the information from Problem 15 and the center of gravity method to determine coordinates for the warehouse.

Town	Coordinates (*X*, *Y*)
A	(4, 18)
B	(12, 2)
C	(10, 8)
D	(8, 15)

17. Shoeless Joe is a specialty retailer that is deciding where to locate a new facility. The annual fixed and variable costs for each possible site have been estimated as follows:

Location	Fixed Costs	Variable Costs
A	$70,000	$1/unit
B	$34,000	$5/unit
C	$20,000	$8/unit
D	$50,000	$4/unit

If demand is expected to be 2000 units, which location is best?

18. The Quick Copy center for document copying is deciding where to locate a new facility. The annual fixed and variable costs for each site it is considering have been estimated as follows:

Location	Fixed Costs	Variable Costs
A	$85,000	$2/unit
B	$49,000	$7/unit
C	$35,000	$10/unit
D	$65,000	$6/unit

If demand is expected to be 3000 units, which location is best?

CASE: Data Tech, Inc.

Data Tech, Inc. is a small but growing company started by Jeff Styles. Data Tech is a business that transfers hard copies of documents, such as invoices, bills, or mailing lists, onto CDs. As more companies move to a paperless environment, placing data on CDs is the wave of the future. Jeff had started the company in his two-car garage three years earlier by purchasing the necessary software and signing two large corporations as his first customers. Now he was about to sign on two additional corporate customers. Suddenly what was a small garage operation was turning into a major business.

The Business

The operations function of Data Tech seems deceptively simple. Every day Data Tech receives packages of mail from corporate customers containing documents they want transferred to disc. Data Tech usually receives anywhere from 10,000 to 30,000 pieces of mail per day that need to be processed. The first step requires workers to unpack and sort the mail received. Next, workers scan each item through one of two scanning machines that transfer content to disc. An accuracy check is then made to ensure that information was transferred correctly. This stage is particularly important as many of the documents contain important private information. Finally, the discs and the documents are packaged and sent back to the customer, with Data Tech keeping a backup disc for its records.

The Need for Capacity and Relocation

Running a full-time business out of his two-car garage is a challenge for Jeff Styles. Jeff has spent a great deal of time ensuring that the operation of Data Tech runs smoothly without any bottlenecks. He has been successful, and his two original customers have just signed long-term contracts with him. In addition, he has acquired two additional customers. This means that Data Tech needs to move to a larger facility that could accommodate the larger size of the business.

Jeff has narrowed his search to three potential locations. He has identified the factors that are important to him and rated each location considering a number of criteria. Some factors are especially important, such as proximity to the postal service that delivers the daily packages. Another is closeness to the airport, as Jeff frequently travels to customer locations.

A factor that is particularly troubling for Jeff is the issue of capacity. Two of the locations he is considering are larger than he currently needs and offer excess growth capacity. The third location would meet current capacity needs but would not offer ample room for expansion. He doesn't know which is a better strategy. In his list of factor weights Jeff has made spaces for both capacity options, giving himself some time to think about the issues.

The information that Jeff has compiled is shown in the table.

Factor	Factor Weight	Factor Score at Each Location #1	#2	#3
Proximity to airport	20	3	4	4
Proximity to postal service	30	4	2	5
Facility with excess capacity	?	4	5	0
Facility with potential for expansion	?	0	1	5
Close to business community	10	5	4	4
Pleasant environment	10	3	4	4

To Expand Large or Small

Jeff is not sure how to evaluate whether he should focus on moving into a larger facility now or moving into a smaller facility with potential for expansion. He has estimated the following chances for demand:

- The likelihood of demand being high is 0.70.
- The likelihood of demand being low is 0.30.

He also estimated profitability for each alternative:

- Moving into a large facility has a profitability of either $1,000,000 or $600,000, depending on whether demand turns out to be high or low.
- Moving into a small facility has a profitability of $500,000, assuming that demand is low.
- Moving into a small facility would require considering expanding if demand turned high. If Data Tech decided to expand at that point, profitability would be $800,000. If it did not expand further, the profitability would be $500,000.

Case Questions

1. Help Jeff decide whether he should give greater priority to a smaller facility with possibility for expansion or move into a larger facility immediately. Decide on which is the best alternative and choose weights for the two capacity factors based on your findings.
2. Once you have selected the factors for the two capacity alternatives, use factor rating to select a new location for Data Tech.
3. How would your factor analysis be different if you had selected a different capacity alternative?

CASE: The Emergency Room (ER) at Northwest General (B)

Jenn Kostich, director of emergency services at Northwest General Hospital, is faced with a decision on how to respond to a recent memo. Her response could affect the entire ER operation, and she wants to make sure it is prepared correctly.

The Problem

Jenn has just learned that the board of Northwest General has approved plans for a large remodeling and expansion project. All department directors of the hospital have been asked to provide an assessment of their capacity needs if they were requesting an increase in their departmental space. The directors were told to specify the amount of increase they required and provide justification for the request. They were also directed to base their requests on the average of their departments' demand requirements.

The ER desperately needs more space, and Jenn is easily able to provide the needed documentation. However, she is not sure whether it is reasonable to base capacity requirements for the ER on average demand.

Background

Northwest General is the only major hospital in the area between Seattle and Vancouver. Its ER is always busy, since it is the only hospital servicing the local population and visitors during the long tourist season.

The area has been stable in population growth over the past 10 years. The area is also a significant tourist destination for campers, hikers, and nature lovers. During the tourist season—consisting of summer months (June, July, and August), winter holidays (December), and spring break (March and April)—the population swells by as much as 30 percent.

The ER has been able to meet demand adequately during the nontourist season. However, it does not have sufficient capacity to meet demand when tourists arrive. These peak periods, amounting to 6 out of 12 months, have been extremely difficult for the ER staff. The ER does not have enough space capacity for the large number of patients during these periods. Frequently, they have to resort to using hallways and closets for patient space. The staff feel that this is unacceptable, not to mention unsafe.

The capacity problems occur only during the busy tourist season. Computing the average of the capacity requirements does not reveal this problem, as the peak demands are averaged with the lower demands during the nontourist season.

Case Questions

1. Discuss the pros and cons of using average demand to assess capacity requirements. Is this a reasonable approach for the ER?
2. Make a recommendation for Jenn as to what she should do and the information that she should provide in her request.

INTERACTIVE CASE Virtual Company

www.wiley.com/college/reid

On-line Case: Cruise International, Inc.

Assignment: *Capacity Analysis at Cruise International, Inc.* Bob Bristol just called to congratulate you on your excellent work on the various assignments at CII. He now wants you to do some capacity analysis for Meghan Willoughby, the Chief Purser. Meghan is concerned about the capacity needed for the embarkation process. If there is too much capacity, it is an unnecessary expense. However, if there is insufficient capacity, passengers are forced to wait in line for too long and their vacation starts with a negative experience. The amount of capacity is flexible as Meghan negotiates arrangements with the owners of the pier used, in terms of both square footage and the amount of time. This assignment will enhance your knowledge of the material in Chapter 9 of your textbook while preparing you for future assignments.

To access the Web site:

- Go to **www.wiley.com/college/reid**
- Click **Student Companion Site**
- Click **Virtual Company**
- Click **Consulting Assignments**
- Click **Capacity Analysis at CII**

INTERNET CHALLENGE EDS Office Supplies, Inc.

EDS is a national distributor of office supplies that delivers goods to department and specialty stores. It is planning to build a large distribution center in your state and is analyzing different location sites. You have been assigned the task of selecting the major city in your state that you think should be the site of the new distribution center. Here are some facts to consider. At present EDS has no other distribution center in your state. The goal is to locate in a major city that has easy access to major roadways; this will enable EDS to reach other destinations in the state. Although your decision will be subjective, be prepared to justify it. Go to the Internet to find a map of your state. Analyze roadways, distances, and access to other locations. Then use the Internet to get other information, such as traffic patterns, populations, and other geographic factors. Decide on the best location for the EDS distribution center and explain your decision.

On-line Resources

WILEY PLUS

Companion Website www.wiley.com/college/reid

- Take interactive *practice quizzes* to assess your knowledge and help you study in a dynamic way
- Review *PowerPoint slides* or print slides for notetaking
- Download *Excel Templates* to use for problem solving
- Access the *Virtual Company: Cruise International, Inc.*
- Find links to *Company Tours* for this chapter
  Northeast Knitting Mills
  Coppley Apparel Group
- Find links for *Additional Web Resources* for this chapter
  The Association for Manufacturing Excellence, *www.ame.org*
  APICS—The Educational Society of Resource Management, *www.apics.org*

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CHAPTER 12

"Independent Demand" Inventory Management

Before studying this chapter, you should know or, if necessary, review

1. Competitive priorities, Chapter 2, pp. 36–42.
2. Internal and external customers, Chapter 4, p. 102.
3. Advantages of small lot sizes, Chapter 7, pp. 243–244.
4. Forecast error, Chapter 8, pp. 291–294.

LEARNING OBJECTIVES

After studying this chapter you should be able to

1. Describe the different types and uses of inventory.
2. Describe the objectives of inventory management.
3. Calculate inventory performance measures.
4. Understand the relevant costs associated with inventory.
5. Perform ABC inventory control and analysis.
6. Understand the role of cycle counting in inventory record accuracy.
7. Understand the role of inventory in service organizations.
8. Calculate order quantities.
9. Evaluate the total relevant costs of different inventory policies.
10. Understand why companies don't always use the optimal order quantity.
11. Understand how to justify smaller order sizes.
12. Calculate appropriate safety stock inventory policies.
13. Calculate order quantities for single-period inventory.

CHAPTER OUTLINE

WHAT'S IN OM FOR ME?

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Have you ever been in a rush to get through the grocery checkout only to be stuck in line behind a person buying numerous varieties of the same general item? Perhaps a person buying 24 cans of pet food, with each can being a different flavor. You watch in dismay as the cashier scans each individual can, wondering why the cashier doesn't just scan one can and enter a quantity of 24. Although it would be much easier to let the cash register do the work, it is critical that the cashier scan each individual can.

Jeff Zaruba/Stone/Getty Images, Inc.

Many retailers, like Wal-Mart, Sears, Victoria's Secret, Home Depot, and Kroger, use point-of-sale cash registers to collect data on each item sold. This information is then used to update their inventory records to determine when a replenishment order should be placed.

When the cashier scans only a single flavor and enters a quantity of 24, the register reports that 24 cans of that specific flavor have been bought by this customer and adjusts the inventory record for that item. In reality, the customer bought 1 can each of 24 different varieties. Failure to scan each item results in all 24 inventory records becoming inaccurate. These inaccurate inventory records cause companies to replenish the wrong items and result in shortages on the shelves.

Information collected with point-of-sale registers is the basis for generating automatic replenishment orders. When making replenishment decisions, a business decides what, when, and how much should be purchased. When a company replenishes the wrong item because of inaccurate inventory records, the customer is often not satisfied. If a company replenishes items too soon because of inaccurate records, it has invested money in unnecessary inventory and risks item spoiling or deteriorating. It is also possible that the company might not have the necessary storage space because of ordering the wrong item.

Companies make replenishment decisions when managing inventory. In this chapter we look at different types of inventory and how companies use those inventories, the costs of different inventory policies, inventory management objectives and performance measures, and techniques for determining how much of an item to replenish.

TYPES OF INVENTORY

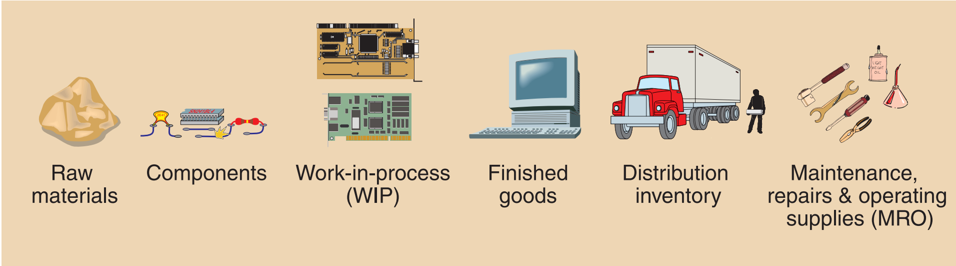
Inventory comes in many shapes and sizes, as shown in Figure 12-1. Most manufacturing firms have the following types of inventory. **Raw materials** are the purchased items or extracted materials that are transformed into components or products. For example, gold is a raw material that is transformed into jewelry. **Components** are parts or subassemblies used in building the final product. For example, a transformer is a component in an electronic product. **Work-in-process (WIP)** refers to all items in process throughout the plant. Since products are not manufactured instantaneously, there is

▶ **Raw materials**
Purchased items or extracted materials transformed into components or products.

▶ **Components**
Parts or subassemblies used in the final product.

FIGURE 12-1

Types of inventory



always some WIP inventory flowing through the plant. After the product is completed, it becomes **finished goods**—the bicycles, stereos, CDs, and automobiles that the company sells to its customers. **Distribution inventory** consists of finished goods and spare parts at various points in the distribution system—for example, stored in warehouses or in transit between warehouses and consumers. *Maintenance, repair, and operational* (*MRO*) *inventory* are supplies that are used in manufacturing but do not become part of the finished product. Examples of MRO are hand tools, lubricants, and cleaning supplies.

▶ **Work-in-process (WIP)** Items in process throughout the plant.

▶ **Finished goods** Products sold to customers.

▶ **Distribution inventory** Finished goods in the distribution system.

HOW COMPANIES USE THEIR INVENTORY

Companies have different kinds of inventory. They also use inventory for different purposes. Let's look at six ways of using inventory.

1. Anticipation Inventory or Seasonal Inventory is built in anticipation of future demand, planned promotional programs, seasonal fluctuations, plant shutdowns, and vacations. Companies build **anticipation inventory** to maintain level production throughout the year. For example, the toy industry builds toys throughout the year in anticipation of high seasonal sales in December.

▶ **Anticipation inventory** Inventory built in anticipation of future demand.

2. Fluctuation Inventory or Safety Stock is carried as a cushion to protect against possible demand variation, "just in case" of unexpected demand. For example, you might keep extra food in the freezer just in case unexpected company drops in. **Fluctuation inventory** or safety stock is also called *buffer stock* or *reserve stock*.

▶ **Fluctuation inventory** Provides a cushion against unexpected demand.

3. Lot-size Inventory or Cycle Stock results when a company buys or produces more than is immediately needed. The extra units of **lot-size inventory** are carried in inventory and depleted as customers place orders. Consider what happens when you buy a 24-can case of soda. You do not normally drink all 24 cans at once. Instead, what you do not need right away, you store for future consumption. You may buy more of an item than you need to take advantage of lower unit costs or quantity discounts. Cycle stock also occurs when making products and the process has a minimum greater than is needed.

▶ **Lot-size inventory** A result of the quantity ordered or produced.

4. Transportation or Pipeline Inventory is in transit between the manufacturing plant and the distribution warehouse. **Transportation inventory** are items that are not available for satisfying customer demand until they reach the distribution warehouse,

▶ **Transportation inventory** Inventory in movement between locations.

so the company needs to decide between using slower, inexpensive transportation or faster, more expensive transportation. To calculate the average amount of inventory in transit, we use the formula

$$ATI = \frac{tD}{365}$$

where ATI = average transportation inventory (in units)
t = transit time (in days)
D = annual demand (in units)

EXAMPLE 12.1

Calculating Average Transportation Inventory

Suppose the Nadan Company, a producer of brass sculptures, needs to ship finished goods from its manufacturing facility to its distribution warehouse. Annual demand at Nadan is 1460 units. The company has a choice of sending the finished goods regular parcel service (three days transit time) or via public carrier, which takes eight days transit time. Calculate the average annual transportation inventory for each of the alternatives. Note that the average transportation inventory does not consider shipment quantity but only transit time and annual demand. To reduce transit inventory, you reduce transit time.

• **Solution:**

When using the regular parcel service,

$$ATI = \frac{3 \times 1460}{365} = 12 \text{ units}$$

When using the public carrier,

$$ATI = \frac{8 \times 1460}{365} = 32 \text{ units}$$

5. Speculative or Hedge Inventory is a buildup to protect against some future event such as a strike at your supplier, a price increase, or the scarcity of a product that may or may not happen. A company typically builds **speculative inventory** to ensure a continuous supply of necessary items. Think about booking an airline flight three months in advance so you can take advantage of a reduced fare. You assume that the airfare will not be reduced further and that you will still need the ticket three months from now. It is a gamble.

▶ **Speculative inventory** Used to protect against some future event.

6. Maintenance, Repair, and Operating (MRO) Inventory includes maintenance supplies, spare parts, lubricants, cleaning compounds, and daily operating supplies such as pens, pencils, and note pads. **MRO** items support general operations and maintenance but are not part of the product the company builds.

▶ **Maintenance, repair, and operating inventory** (**MRO**) Items used in support of manufacturing and maintenance.

Inventory plays multiple roles in a company's operations. For this reason, companies develop inventory management objectives and performance measures to evaluate how well they are handling their inventory investment. The six functions of inventory are summarized in Table 12-1.

TABLE 12-1

Functions of Inventory

Anticipation inventory	Items built in anticipation of future demand. Allows company to maintain a level production strategy.
Fluctuation inventory	Protects against unexpected demand variations. Assures customer service levels.
Lot-size inventory	Results from the actual quantity purchased. Allows for lower unit costs.
Transportation inventory	Items in movement between locations. Inventory moves from manufacturer to distribution facilities.
Speculative inventory	Extra inventory built up or purchased to protect against some future event. Allows for continuous supply.
MRO	Includes maintenance supplies, spare parts, lubricants, cleaning agents, and daily operating supplies. Facilitates day-to-day operations.

OBJECTIVES OF INVENTORY MANAGEMENT

MKT

The objectives of inventory management are to provide the desired level of customer service, to allow cost-efficient operations, and to minimize the inventory investment.

Customer Service

▶ **Customer service** The ability to satisfy customer requirements.

▶ **Percentage of orders shipped on schedule** A customer service measure appropriate for use when orders have similar value.

What is customer service? **Customer service** is a company's ability to satisfy the needs of its customers. When we talk about customer service in inventory management, we mean whether or not a product is available for the customer when the customer wants it. In this sense, customer service measures the effectiveness of the company's inventory management. Customers can be either external or internal: any entity in the supply chain is considered a customer.

Suppose your company, Kayaks!Incorporated, offers a line of kayaks and kayaking equipment through catalog sales and an accompanying Web site. As product manager, you need to know whether the inventory management system you introduced is effective. One way to measure its effectiveness would be to measure the level of customer service: are customers getting the kayaking equipment they request, and are their orders shipped on time? To answer your questions, you can measure the percentage of orders shipped on schedule, the percentage of line items shipped on schedule, the percentage of dollar volume shipped on schedule, or manufacturing idle time due to inventory shortages.

Mike Timo/Stone/Getty Images, Inc.

Good inventory management results in satisfied customers.

Percentage of Orders Shipped on Schedule is a good measure for finished goods customer service, such as your kayaking equipment company, if all orders and customers have similar value and late deliveries are not excessively late. For a different kind of company, such as one that designs computer networks, some customers have much greater value. Obviously, this method does not adequately capture the value of those customers' orders.

For example, if the book publishing company John Wiley & Sons, Inc. represents 50 percent of your demand but is only 1 out of 20 orders on the schedule, delivering late to Wiley is certainly more harmful to your company than shipping a smaller order late. With this measure, however, all late orders are treated equally. If you have only

one late shipment, the customer service level is 95 percent (19 of 20 shipped on schedule). But if the late order is to Wiley, you have met only 50 percent of your demand.

Percentage of Line Items Shipped on Schedule recognizes that not all orders are equal but fails to take into account the dollar value of orders. This measure needs more information—the number of line items instead of the number of orders—than the previous measure. Therefore, this measure is more expensive to use and is most appropriate for finished goods inventory.

▶ **Percentage of line items shipped on schedule** A customer service measure appropriate when customer orders vary in number of line items ordered.

As an example of the percentage of line items shipped on schedule, consider the following. Your sister company, White Water Rafts, Inc., determines that from the 20 orders scheduled for delivery this month, customers requested 250 different line items. White Water can ship 225 of these line items on schedule. Their customer service level is 90 percent (225 items shipped on time divided by 250 line items requested).

Percentage of Dollar Volume Shipped on Schedule recognizes the differences in orders in terms of both line items and dollar value. Instead of measuring line items to determine the customer service level, a company totals the value of the orders. For example, if the 20 orders to the Palm Pilot™ handheld-computer manufacturing company had a total value of $400,000 and the company shipped on schedule handheld computers valued at $380,000, the customer service level is 95 percent ($380,000 shipped, divided by $400,000 ordered).

▶ **Percentage of dollar volume shipped on schedule** A customer service measure appropriate when customer orders vary in value.

Courtesy Palm, Inc.

Customer service of Palm handheld computers can be measured as a percentage of dollar volume shipped on schedule.

Idle Time Due to Material and Component Shortages applies to internal customer service. This is an absolute measure of the manufacturing or service time lost because material or parts are not available to the workforce. Absolute measures make sense when a company has historical data to use in comparisons. For example, Kayaks!Incorporated's supplier historically has lost no more than two manufacturing days per year because of material and component shortages. This year, however, it has lost four manufacturing days for this reason. Obviously, this year's case is worse and needs management's attention.

These are only a few of the measures companies use to evaluate customer service. The desired level of customer service should be consistent with the company's overall strategy. If customer service is your company's competitive advantage, the company must achieve a very high level of customer service. Even when customer service isn't the primary focus, your company must still maintain an acceptable level of customer service.

Now let's look at how inventory helps manufacturers operate efficiently.

Cost-Efficient Operations

Companies can achieve *cost-efficient operations* by using inventory in the following ways. First, companies use work-in-process (WIP) inventory to buffer operations. Suppose one of the Hewlett-Packard (HP) printed circuit board (PCB) manufacturing facilities runs two or more operations in a sequence at different rates of output. In this case, buffer inventories build up between the workstations to ensure that each of the operations runs efficiently. For example, PCBs flow from Ken's workstation (tasks take 120 seconds) to Barbara's workstation (tasks take only 90 seconds). If there are no PCBs between the two workstations, Barbara will be idle for 30 seconds out of every 120 seconds because she finishes her tasks 30 seconds before Ken finishes his.

MKT

If the floor supervisor, Maria, ensures that there is buffer stock between the workstations, Barbara's idle time will be eliminated so she can produce more PCBs.

Second, inventories allow manufacturing organizations to maintain a level workforce throughout the year despite seasonal demand for production. (Level production plans are discussed in Chapter 13.) A company can do this by building inventory in advance of seasonal demands. This in turn allows the company to maintain a level workforce throughout the year and to reduce the costs of overtime, hiring and firing, training, subcontracting, and additional capacity.

▶ **Setup cost**
Costs such as scrap costs, calibration costs, and downtime costs associated with preparing the equipment for the next product being produced.

Third, by building inventory in long production runs, the **setup cost** is spread over a larger number of units, decreasing the per unit setup cost. Setup costs include the cost of scrap (wasted material and labor), calibration, and downtime to prepare the equipment and materials for the next product to be manufactured. Longer runs mean that the equipment does not need as many setups, so less machine time is lost preparing for production.

Fourth, a company that is willing to acquire inventory can buy in larger quantities at a discount. These larger purchases decrease the ordering cost per unit. For example, the Rustic Garden Furniture Company needs 50,000 pieces of wrought iron annually. Rustic's supplier has offered a unit price of \$1.10 if Rustic buys the wrought iron in orders of 10,000 or more pieces at a time. If Rustic chooses to buy in smaller quantities, the unit price is \$1.29.

Now let's look at ways to measure inventory investment.

Minimum Inventory Investment

▶ **Inventory turnover**
A measure of inventory policy effectiveness.

A company can measure its *minimum inventory investment* by its **inventory turnover**—that is, by the level of customer demand satisfied by the supply on hand. We calculate the inventory turnover measure as

$$\text{Inventory turnover} = \frac{\text{annual cost of goods sold}}{\text{average inventory in dollars}}$$

EXAMPLE 12.2

Computing Inventory Turns

If the annual cost of goods sold at the Nadan Company is \$5,200,000 and the average inventory in dollars is \$1,040,000, what is the inventory turnover?

• **Solution:**

$$\text{Inventory turnover} = \frac{\$5{,}200{,}000}{\$1{,}040{,}000} = 5 \text{ inventory turns}$$

The ratio at the Nadan Company should be compared with that achieved by other companies within the industry. Although there is no magic number for inventory turnover, the higher the number, the more effectively the company is using its inventory. One measure of the level of demand that can be satisfied by on-hand inventory is **weeks of supply**. Weeks of supply is calculated by dividing the average on-hand inventory by the average weekly demand.

▶ **Weeks of supply**
A measure of inventory policy effectiveness.

$$\text{Weeks of supply} = \frac{\text{average inventory on hand in dollars}}{\text{average weekly usage in dollars}}$$

EXAMPLE 12.3

Calculating Weeks of Supply

Suppose that the Nadan Company wants to calculate its weeks of supply. From the previous example, we know that annual cost of goods sold is $5,200,000.

• Solution:

To determine the weekly cost of goods sold, we divide the annual cost of goods sold by 52 weeks ($5,200,000/52 = $100,000). Given that Nadan maintains an average inventory of $1,040,000, we calculate the weeks of supply as follows:

$$\text{Weeks of supply} = \frac{\$1{,}040{,}000}{\$100{,}000} = 10.4 \text{ weeks of supply}$$

Note that there is a relationship between inventory turnover and weeks of supply. If you divide total weeks per year (52) by the weeks of supply (10.4), you see that the answer is the same as when you calculated inventory turnover. If you divide total number of weeks (52) by the inventory turnover rate (5), the answer is 10.4 weeks of supply. In some companies, inventory performance is measured in either days or hours of supply. To calculate days of supply, we use the formula

$$\text{Days of supply} = \frac{\text{average inventory on hand in dollars}}{\text{average daily usage in dollars}}$$

and hours of supply is calculated as

$$\text{Hours of supply} = \frac{\text{average inventory on hand in dollars}}{\text{average hourly usage in dollars}}$$

Let's look at an example using both of these measures.

EXAMPLE 12.4

Calculating Inventory Supply at the Jenny Company

Suppose that the Jenny Company, a specialty gift organization, wants to calculate its days of supply. The annual cot of goods sold is $1,300,000, the average inventory is $15,600, and the company operates 250 days per year.

• Solution:

First, we calculate the average daily usage. We divide the annual cost of goods sold by the number of days the company operates ($1,300,000 divided by 250 days equals $5200). Second, using the formula, we divide the average inventory on hand by the average daily usage.

$$\text{Days of supply} = \frac{\$15{,}600}{\$5200} = 3 \text{ days of supply}$$

Suppose the Jenny Company uses a new process that reduces the average inventory held to $3250. To calculate its current hours of supply, we first calculate the average hourly usage. Using the data provided and assuming an eight-hour day, we divide the average daily usage ($5200) by eight hours. The average hourly usage is $650. Therefore, the hours of supply are

$$\text{Hours of supply} = \frac{\$3250}{\$650} = 5 \text{ hours of supply}$$

TABLE 12-2

Inventory Objectives

	Inventory Objectives
Customer service	Measured by any of the following: • Percentage of orders shipped on schedule • Percentage of line items shipped on schedule • Percentage of dollar volume shipped on schedule • Idle time due to component and material shortages
Cost-efficient operations	Inventories help achieve cost-effective operations by • Using buffer stock to assure smooth production flow • Maintaining a level workforce • Allowing longer production runs, which spreads the cost of setups • Taking advantage of quantity discounts
Minimum inventory investment	Measured by any of the following: • Inventory turnover • Weeks of supply • Days of supply

Table 12-2 summarizes the inventory objectives we just discussed.

RELEVANT INVENTORY COSTS

Inventory management policies have cost implications. Decisions about how much inventory to hold affect item costs, holding costs, ordering costs, and stockout (shortage) costs.

Item Costs

▶ **Item cost**
Includes price paid for the item plus other direct costs associated with the purchase.

The **item costs** of a purchased item include the price paid for the item and any other direct costs for getting the item to the plant, such as inbound transportation, insurance, duty, or taxes. For an item built by the manufacturing company, the item costs include direct labor, direct materials, and factory overhead.

Holding Costs

▶ **Holding costs**
Include the variable expenses incurred by the plant related to the volume of inventory held.

▶ **Capital costs**
The higher of the cost of capital or the opportunity cost for the company.

Holding costs include the variable expenses incurred by the firm for the volume of inventory held. As inventory increases, so do the holding costs. We can determine unit holding costs by examining three cost components: capital costs, storage costs, and risk costs. Annual holding costs are typically stated in either dollars per unit ($3.50 per unit per year) or as a percentage of the item value (25 percent of the unit value).

Capital costs are the higher of either the cost of the capital or the opportunity cost for the company. The cost of the capital is the interest rate the company pays to

borrow money to invest in inventory. The opportunity cost is the rate of return the company could have earned on the money if it were used for something other than investing in inventory. The opportunity cost is at least as much as the interest the company could get at the prevailing interest rate. It may be higher if more lucrative opportunities are available. Suppose you have a startup company and need to finance your inventory with a bank loan at 8 percent. Or the company can invest its capital in the stock market and generate a 20 percent return on the investment. For its capital cost, the company would use the 20 percent opportunity cost rather than the 8 percent cost of the loan. The capital cost is typically expressed as an annual interest rate.

Storage costs usually include the cost of space, workers, and equipment. For our purposes, however, we are concerned only with the additional out-of-pocket expenses resulting from the size of the inventory. For example, we include the cost of storage space if it is public warehousing and varies based on the amount of inventory held. If the company already owns the storage space and incurs no additional expense for storing the inventory, we do not include it in the holding cost. The same is true for employees. If an employee works overtime because of the level of inventory, this is an out-of-pocket expense and needs to be included. However, if the employee's workload is merely higher during the normal day, the cost of the employee is not included.

▶ **Storage costs**
Include the variable expenses for space, workers, and equipment related to the volume of inventory held.

Risk costs include obsolescence, damage or deterioration, theft, insurance, and taxes. These costs vary based on industry. Companies operating in a high-tech environment typically experience much greater obsolescence and theft. Companies that manufacture consumer products may find higher levels of theft.

▶ **Risk costs**
Include obsolescence, damage or deterioration, theft, insurance, and taxes associated with the volume of inventory held.

In general, risk costs are associated with higher levels of inventory. The more inventory you have, the longer it lasts—therefore, the greater the chance of it becoming obsolete. The more inventory you have sitting around, the more likely it is to be damaged. Think of walking through an overloaded basement: you bump into something; it falls and breaks. Theft also typically increases as inventory increases. When a company has few items in inventory, it is more noticeable when an item disappears. However, if the company has a lot of inventory, it is harder to notice when only one item disappears. Insurance costs are typically based on the value of the inventory, so larger inventories have higher insurance premiums. The same is true for taxes: the more valuable the inventory, the higher the tax.

Although many textbooks use an annual holding cost of between 20 percent and 30 percent, in real life it depends on the type of business. The risk costs can vary significantly. Let's look at how annual holding costs are calculated.

EXAMPLE 12.5
Calculating Annual Holding Costs

The Nadan Company currently maintains an average inventory of $1,040,000. The company estimates its capital cost at 12 percent, its storage costs at 5 percent, and its risk costs at 8 percent. Calculate the annual holding costs for the Nadan Company.

• **Solution:**

Annual holding cost per unit of inventory equals 25 percent (capital cost + storage costs + risk costs).

$$\text{Annual cost of holding inventory} = \$1{,}040{,}000 \times 0.25 = \$260{,}000$$

Ordering Costs

▶ **Ordering costs**
The fixed costs associated with either placing an order with a supplier or setup costs incurred for in-house production.

Ordering costs are fixed costs for either placing an order with a supplier for a purchased component or raw material or for placing an order to the manufacturing organization for a product built in-house. When you buy an item, the ordering costs include the cost of the clerical work to prepare, release, monitor, and receive orders and the physical handling of the goods. The ordering costs are considered constant regardless of the number of items or the quantities ordered. For example, if the cost to place an order is estimated at $100, every time you place an order with a supplier, the ordering cost is constant ($100).

When an order is released for manufacturing in-house, the ordering or setup costs are the clerical work to prepare the manufacturing order and the list of materials to be picked up and delivered to the manufacturing location, plus the cost to prepare the equipment for the job (calibration, appropriate jigs and fixtures, etc.). Like the ordering costs for purchased items, the ordering or setup costs for jobs done in-house are constant.

Shortage Costs

▶ **Shortage costs**
Incurred when demand exceeds supply.

▶ **Back order**
Delaying delivery to the customer until the item becomes available.

▶ **Lost sale**
Occurs when the customer is not willing to wait for delivery.

MKT

Companies incur **shortage costs** when customer demand exceeds the available inventory for an item. Suppose a customer, Tom Martin, places an order through your kayaking equipment Web site for a high-end kayak, but that kayak is out of stock. One of two things happens. Either Tom allows you to **back-order** the kayak—that is, Tom is willing to wait until the kayak is available—or Tom decides to buy the kayak from another company and the result for your company is a **lost sale**.

In both cases, your company incurs shortage costs. In the case of the back order, shortage costs result from the additional paperwork to track the order and the possible added expense of overnight shipping rather than normal delivery. There is also the lost customer goodwill, an intangible cost. Although Tom accepted the delay this time, you have no guarantee that he will buy from your company again. In the case of the lost sale, the shortage costs typically include loss of the possible profit, plus loss of the contribution to overhead costs. Your company also faces the risk that Tom will not return with future orders. Shortage costs can also result from internal parts shortages, including the cost of downtime due to lack of materials, additional setups, premium transportation costs, and so forth.

ABC INVENTORY CLASSIFICATION

▶ **Pareto's law**
Implies that about 20 percent of the inventory items will account for about 80 percent of the inventory value.

▶ **ABC classification**
A method for determining level of control and frequency of review of inventory items.

All items in a company's inventory are not equal and do not need the same level of control. Fortunately, we can apply **Pareto's law** to determine the level of control needed for individual items. Pareto's law implies that roughly 10 to 20 percent of a company's inventory items account for approximately 60 to 80 percent of its inventory costs. These relatively few high-dollar-volume items are classified as A items. Moderate-dollar-volume items, roughly 30 percent of the items, account for about 25 to 35 percent of the company's inventory investment. These are classified as B items. Low-dollar-volume items, about 50 to 60 percent of the items, represent only 5 to 15 percent of the company's inventory investment and are classified as C items. These percentages are not absolute and are used only as guidelines to determine an item's **ABC classification**.

EXAMPLE 12.6

ABC Analysis at Auto Accessories Unlimited (AAU)

AAU is considering doing an ABC analysis of its entire inventory but has decided to test the technique on a small sample of 15 of its stock-keeping units. The annual usage and unit cost for these items are shown in the table.

(a) Calculate the annual dollar volume for each item.
(b) List the items in descending order based on annual dollar usage.
(c) Calculate the cumulative annual dollar volume.
(d) Group the items into classes.

ABC Problem Data

Item	Unit $ Value	Annual Usage (in units)
101	12.00	80
102	50.00	10
103	15.00	50
104	50.00	40
105	40.00	80
106	75.00	220
107	4.00	250
108	1.50	400
109	2.00	250
110	25.00	500
111	5.00	450
112	7.50	80
113	3.50	250
114	1.00	1200
115	15.00	300

• **Before You Begin:** To do an ABC analysis, you need to know the annual usage and the value of each item. That information is provided for you in the problem data. Multiply the unit value by the annual usage of the item to determine the annual dollar volume for each item. Now list the items in descending order based on annual dollar usage. You can now calculate the percentage of the total inventory value each part represents. This allows you to classify the items into groups.

• **Solution:**

(a)

ABC Annual Usage Values

Item	Unit $ Value	Annual Usage (in units)	Annual Usage ($)
101	12.00	80	960
102	50.00	10	500
103	15.00	50	750
104	50.00	40	2,000
105	40.00	80	3,200
106	75.00	220	16,500
107	4.00	250	1,000
108	1.50	400	600
109	2.00	250	500
110	25.00	500	12,500
111	5.00	450	2,250
112	7.50	80	600
113	3.50	250	875
114	1.00	1200	1,200
115	15.00	300	4,500
		Total	$47,935

(b, c, and d)

ABC Solution

Item	Annual Usage ($)	Percentage of Total Dollars	Cumulative Percentage of Total Dollars	Item Classification
106	16,500	34.4	34.4	A
110	12,500	26.1	60.5	A
115	4,500	9.4	69.9	B
105	3,200	6.7	76.6	B
111	2,250	4.7	81.3	B
104	2,000	4.2	85.5	B
114	1,200	2.5	88.0	C
107	1,000	2.1	90.1	C
101	960	2.0	92.1	C
113	875	1.8	93.9	C
103	750	1.6	95.5	C
108	600	1.3	96.8	C
112	600	1.3	98.1	C
102	500	1.0	99.1	C
109	500	1.0	100.1*	C
Total	**$47,935**			

*Total exceeds 100% due to rounding.

Remember that these are not absolute rules for classifying items. Your company wants to group their more valuable items together to make sure that they get the most control.

Procedure for an ABC Inventory Analysis

The first step for an ABC inventory analysis is to determine the annual usage for each item. We calculate the total annual dollar volume by multiplying the annual usage by the item cost. We then rank items in descending order based on total dollar volume and calculate the total inventory investment.

1. Calculate the annual dollar usage for each item.
2. List the items in descending order based on annual dollar usage.
3. Calculate the cumulative annual dollar volume.
4. Classify the items into groups.

Figure 12-2 graphically depicts the results of the ABC classification. The A items, 106 and 110, combine for 60.5 percent of the total dollar value in inventory and approximately 13.3 percent of the items in inventory. The B items, 115, 105, 111, and 104, account for 25 percent of the total dollar value and 26.7 percent of the items. The C items make up the last 14.5 percent of the total dollar value and 60 percent of the items.

Inventory Control Using ABC Classification

► **Continuous review system** Updates inventory balances after each inventory transaction

After classifying inventory items into A, B, and C classes, we can determine the appropriate level of inventory control. For our most important and expensive A items, we need very tight control, highly accurate inventory records, and frequent or continuous review. A **continuous review system** keeps track of an inventory item 24/7. It tracks every inventory transaction as it occurs, whether it is more material going into inventory or material being withdrawn from the stockroom. Consequently, the EOQ model

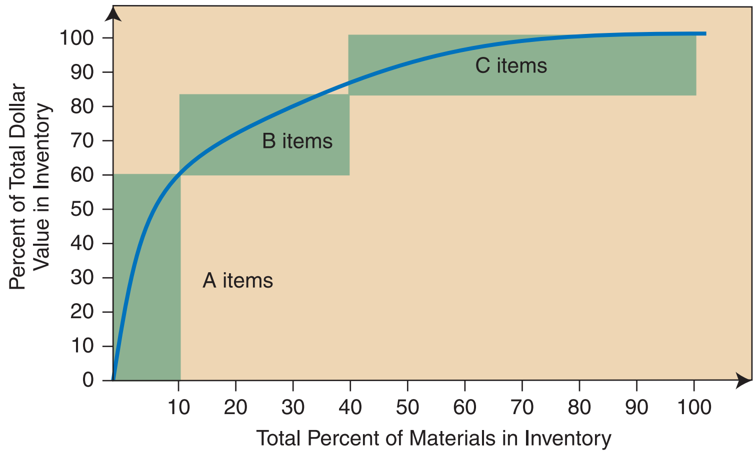


FIGURE 12-2

ABC classification of materials

(discussed later in this chapter) is often used. B items need normal control, moderately accurate inventory records, and a reasonable time period between reviews. For B items, a **periodic review system** (discussed later in this chapter) can be used. A periodic review system reviews the inventory level of the item at regular intervals (daily, weekly, monthly) to determine whether a replenishment order is needed. C items require the least amount of control. Possible options for C items are the **two-bin system** or an infrequent periodic review system. A two-bin system splits an incoming replenishment order into two separate bins. One bin is placed on the factory floor so workers can take what they need. The other bin is kept in the storeroom. This second bin should have enough items to cover normal demand during the replenishment **lead time**. Lead time is the amount of time it takes from order placement until the ordered item is received. When the bin on the floor is empty, workers go to the stockroom to request additional material. The bin in the stockroom is released to the workers on the floor and a replenishment order is placed.

▶ **Periodic review system**
Requires regular periodic reviews of the on-hand quantity to determine the size of the replenishment order.

▶ **Two-bin system**
One bin with enough stock to satisfy demand during replenishment time is kept in the storeroom; the other bin is placed on the manufacturing floor.

▶ **Lead time**
Time from order placement to order receipt.

INVENTORY RECORD ACCURACY

For effective inventory use, the inventory records must accurately reflect the quantity of materials available. Inaccurate inventory records can result in lost sales (finished good not available at time of sale), disrupted operations (not enough of a component or raw material to complete a job), poor customer service (late deliveries to customers), lower productivity (additional setups to complete a job), poor material planning (the inventory records are critical in determining MRP quantities), and excessive expediting (trying to obtain necessary items in less than normal lead time).

One exceptionally productive approach to inventory management is the automated inventory tracking system used by the very successful Cisco Systems—a world leader in providing networking solutions for all types of businesses. This tracking system forms an intricate network of suppliers, manufacturers, and customers and provides for real-time transactions. When a customer places an order via

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LINKS TO PRACTICE

Cisco Systems, Inc.
www.cisco.com

the Internet, suppliers can instantaneously see what parts are needed and can quickly respond by shipping the needed parts and then restocking. Such a system provides accurate, timely information, which helps both Cisco and suppliers to schedule, budget, and forecast. Since most of Cisco's orders are transacted over the Web, Cisco is able to save millions of dollars annually.

Inventory record errors occur because of unauthorized withdrawals of material, unsecured stockrooms, inaccurate paperwork, and/or human errors. Since an accurate database is needed to successfully use the information systems, it is important to detect errors in the inventory records. Two methods are available for checking inventory record accuracy: periodically counting all of the items (typically annually) and cyclically counting specified items (typically daily).

▶ **Periodic counting**
A physical inventory is taken periodically, usually annually.

Periodic counting satisfies auditors that the inventory records accurately reflect the value of the inventory on hand. For material planners, the physical inventory is an opportunity to correct errors. The four steps in taking a physical inventory are

1. Count the quantity of the item and record the count on a ticket attached to the item.
2. Verify by recounting.
3. After verification, collect the tickets.
4. Reconcile inventory records with actual counts. For major discrepancies, investigate further. For minor discrepancies, adjust the inventory records.

Taking physical inventories does not always improve inventory record accuracy. In many cases, companies close down manufacturing to take the physical inventory; the job is often rushed and is typically done by employees not trained for checking inventory. In some cases, inventory record errors are increased rather than reduced. The other alternative method is cycle counting.

▶ **Cycle counting**
Prespecified items are counted daily.

Cycle counting is a method of counting inventory throughout the year. This is a series of mini-physical inventories done daily of some prespecified items. The frequency of counting a particular item depends on the importance and value of the item. Typically, A items are counted most frequently.

The advantages of cycle counting are

- Timely detection and correction of inventory record problems.
- Elimination of lost production time since the company does not need to shut down operations.
- The use of employees dedicated to cycle counting.

Scheduling individual item counts can be done in several ways. An item can be counted just before a replenishment order is placed. At this time, the planner has an accurate count of the item on hand and can determine whether a replenishment order is needed. The quantity to be counted also is relatively low. A planner also can choose to count when new orders arrive. This way, the inventory is at its lowest level. Remember that most replenishment orders arrive just as the on-hand inventory is running out. Another possibility is to schedule a count after a certain number of transactions have occurred. For example, a planner can request a physical count after every 20 transac-

tions involving a particular item. Since errors typically occur during transactions, the greater the number of transactions, the more likely an error will be introduced. One other possibility is to do a count whenever an error is detected. This allows for corrective action to be taken immediately. Regardless of the method, the intent is to improve inventory record accuracy.

In some cases, companies have shifted the burden of inventory accuracy and replenishment decisions to their vendor. **Vendor-managed inventory (VMI)** requires the vendor to maintain an inventory of certain items at the customer's facility. The supplier still owns the inventory until the customer actually withdraws it for use. At that time, the customer pays for the items. The customer does not have to order any of the inventory, as the supplier is responsible for maintaining an adequate supply. Companies use this approach most frequently with lower-level C items that have a relatively standard design.

▶ **Vendor-managed inventory (VMI)**
The supplier maintains an inventory at the customer's facility.

INVENTORY IN SERVICE ORGANIZATIONS

When we compare service organizations with manufacturing organizations, a major difference is that manufacturers have tangible inventory while service providers typically do not. However, extensive tangible inventory is required in wholesale and retail services. How well this inventory is managed often determines whether a service provider is profitable. Consider the importance of inventory in the food service business, especially highly perishable food items. If a manager orders too much of an item, spoilage can occur; if not enough is ordered, customer orders can be lost. It is a constant struggle to order just the right amount of perishable items. Any inventory that perishes, is damaged, or is stolen prior to its actual sale is an inventory loss. In retailing, it is considered good performance when a company has an inventory loss of only 1 percent or less. Some companies face losses exceeding 3 percent of the value of their inventory. Since retailers deal with desirable consumer goods, it is critical for retailers to practice good inventory control and maintain accurate inventory records. To achieve good inventory control, retailers, wholesalers, and food service providers should do the following:

- Select, train, and discipline personnel. It is critical to select good, honest, reliable personnel because employees have direct access to desirable merchandise.
- Have tight control over incoming shipments. Many firms track incoming shipments through bar code scanning and radio frequency identification systems (RFIDs). Shipments are read into the system, and quantities are reconciled with purchase orders. Each item must have a unique stock-keeping unit (SKU).
- Have tight control over items leaving the facility. This is often done with bar code scanners so that point-of-sale (POS) information can be fed into the system to maintain inventory record accuracy. It is critical that stores train personnel in proper scanning techniques to make sure inventory records remain accurate. Attempts to defeat theft include antitheft magnetic strips or security fixtures attached directly to the merchandise. These are used to activate security alarms as a person exits the facility with unpaid merchandise. Other retailers have personnel stationed near the exits for direct observation of customers leaving the store. In some stores in high-loss areas, one-way mirrors can be used as well as direct video surveillance.

Successful wholesaling, retailing, or food service operations require very good inventory control with accurate records. An additional problem, other than theft, facing many retailers is the inability to locate specific merchandise. It is not uncommon for customers to change their minds and simply place merchandise they no longer want in a convenient spot, not necessarily anywhere close to where it belongs. It is also common for clerks returning merchandise to the floor (either items from dressing rooms or items picked up that had been misplaced) to neglect to place the merchandise exactly where it belongs. Being unable to find items can lead to poorer customer service and unnecessary replenishment orders. The success of service organizations using a tangible product depends on practicing good inventory control.

Before You Go On

Before you continue further into the chapter, you need to be sure that you understand the relevant inventory costs. Item cost, holding cost, ordering cost, and shortage cost are summarized in Table 12-3. The next section of this chapter focuses on determining order quantities and uses inventory cost information.

TABLE 12-3 Relevant Inventory Costs

Item cost	Price paid per item plus any other direct costs associated with getting the item to the plant
Holding costs	Capital, storage, and risk costs
Ordering costs	Fixed, constant dollar amount incurred for each order placed
Shortage costs	Loss of customer goodwill, back-order handling, and lost sales

DETERMINING ORDER QUANTITIES

The objectives of inventory management are to provide the desired level of customer service, enable cost-efficient operations, and minimize the inventory investment. To achieve these objectives, a company must first determine how much of an item to order at a time.

▶ **Stock-keeping unit** (SKU) An item in a particular geographic location.

Inventory management and control are done at the level of the individual item or **stock-keeping unit** (**SKU**). An SKU is a specific item at a particular geographic location. For example, a pair of jeans, size 32 × 32, in inventory at the plant and also eight different warehouses, represents nine different SKUs. A pair of the same jeans held at the same locations but a different size (32 × 34) represents nine additional SKUs. The same style of jeans in a different color represents additional SKUs.

Let's look at how a company determines how much of an SKU to order. We will consider some common approaches in this section, summarized in Table 12-4. In the next section we will look at mathematical models for determining order quantity.

TABLE 12-4

Common Ordering Approaches

Lot-for-lot	Order exactly what is needed.
Fixed-order quantity	Order a predetermined amount each time an order is placed.
Min-max system	When on-hand inventory falls below a predetermined minimum level, order a quantity that will take the inventory back up to its predetermined maximum level.
Order *n* periods	Order enough to satisfy demand for the next *n* periods.

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SKUs at a retail store

Lot-for-lot is ordering exactly what you need. You adjust the ordering quantity to your ordering needs, which ensures that you will not have leftover inventory. You use lot-for-lot when demand is not constant and you have information about expected needs. Ordering sandwiches for a business lunch meeting is a good example of when to use lot-for-lot. The number of persons attending the meeting can vary based on the meeting topic. Since sandwiches are perishable, you do not want to have leftover inventory. This system is also commonly used in material requirements planning (MRP) systems, which we discuss in Chapter 14.

▶ **Lot-for-lot**
The company orders exactly what is needed.

Fixed-order quantity specifies the number of units to order each time you place an order for a certain SKU or item. The quantity may be arbitrary (perhaps 100 units at a time), or it may be the result of how the item is packaged or prepared (such as 144 per box or a loaf of bread). The advantage of this system is that it is easily understood; the disadvantage is that it does not minimize inventory costs.

▶ **Fixed-order quantity**
Specifies the number of units to order whenever an order is placed.

The **min-max system** involves placing an order when the on-hand inventory falls below a predetermined minimum level. The quantity ordered is the difference between the quantity available and the predetermined maximum inventory level. For example, if the minimum is set at 50 units, the maximum is set at 250 units, and the quantity available at the time of the order is 40 units, the order quantity is 210 units (250 − 40). With this system, both the time between orders and the quantity ordered can vary.

▶ **Min-max system**
Places a replenishment order when the on-hand inventory falls below the predetermined minimum level. An order is placed to bring the inventory back up to the maximum inventory level.

Order *n* periods means that you determine the order quantity by summing your company's requirements for the next *n* periods. Suppose you have to order enough each time you place an order to satisfy your company's requirements for the next three periods. If these requirements for the next three weeks are 60, 45, and 100, your order is for 205 units. A concern with this system is determining the number of periods to include in the order.

▶ **Order *n* periods**
The order quantity is determined by total demand for the item for the next *n* periods.

MATHEMATICAL MODELS FOR DETERMINING ORDER QUANTITY

Now let's look at some mathematical models that determine order quantity and minimize inventory costs, beginning with the economic order quantity (EOQ) model.

Economic Order Quantity (EOQ)

The **economic order quantity model (EOQ)** has been around since the early 1900s and remains useful for determining order quantities. EOQ is a continuous review system, used to keep track of the inventory on hand each time stock is added or

▶ **Economic order quantity model (EOQ)**
An optimizing method used for determining order quantity and reorder points.

withdrawn. If the withdrawal reduces the inventory level to the reorder point or below, you make a replenishment order.

Thus, EOQ tells you when to place a replenishment order and determines the order quantity that minimizes annual inventory cost. Suppose you decide that your kayaking equipment company needs to place a replenishment order whenever the inventory level of item K310 reaches 100 units. Right now you have 105 units of item K310 in inventory. You withdraw 5 K310s to satisfy a customer order, resulting in an updated inventory level of 100 units. Since the inventory level has reached the reorder point, it is time to place a replenishment order for K310. A key characteristic of the continuous review system is that it keeps track of inventory as it is withdrawn.

In the following section we look at some assumptions made by the basic EOQ model.

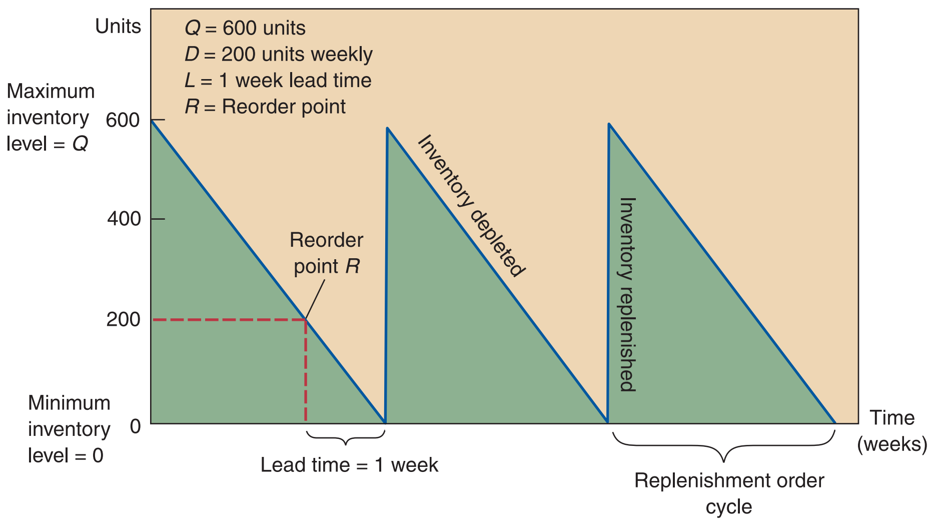
EOQ Assumptions The basic EOQ model makes these assumptions:

- Demand for the product is known and constant. This means that we know how much the demand is for every time period and that this amount never changes. For example, demand is 50 units per week every week or 10 units per day every day. This assumption is indicated by the straight line that shows the depletion of our inventory in Figure 12-3.
- Lead time is known and constant. It is the amount of time it takes from order placement until it arrives at the manufacturing company (for example, 10 working days between order placement and receipt of merchandise).

  Because you know how long it takes for the replenishment order to arrive, you can determine when you need to place the order. By finding the reorder point (shown in Figure 12-3), you schedule the arrival of the replenishment quantity just as your company's inventory level reaches zero. The minimum inventory level with the basic EOQ should be zero.
- Quantity discounts are not considered: the cost of all units is the same, regardless of the quantity ordered. (We discuss this in more detail later in the chapter.)
- Ordering and setup costs are fixed and constant: the dollar amount to place an order is always the same, regardless of the size of the order.

FIGURE 12-3

The EOQ model



- Since the company knows demand with certainty, the assumption is that all demand is met. The basic model does not permit back orders, but more advanced models are less rigid.
- The quantity ordered arrives at once, as shown in Figure 12-3. Since the order is scheduled to arrive just as the company runs out of inventory, the maximum inventory level equals the economic order quantity.

Figure 12-3 shows the basic workings of the EOQ model. The inventory replenishment process begins when the inventory reaches the reorder point. This is the point at which you place an order for Q units, which are timed to arrive just as your company's inventory level reaches zero. The inventory goes from zero to Q and then is depleted at a constant rate. Once the inventory reaches the reorder point, the process begins again.

Since the basic model assumes certainty about demand and lead time, the reorder point is set equal to demand during lead time, or

$$R = dL$$

where R = reorder point
d = average daily demand
L = lead time in days

Problem-Solving Tip When solving for R, it is possible to use other than daily demand and lead time in days. Use whatever is convenient. If lead time is given in weeks, then use average weekly demand. If lead time is given in months, then use average monthly demand.

For example, if average daily demand is 40 units and lead time is five days, then the reorder point is 200 (40 units times five days). When the inventory reaches 200, it is time to place an order.

Calculating Inventory Policy Costs Since companies are interested in the costs associated with inventory policies, let's calculate the annual ordering or setup costs and the annual holding costs associated with the basic EOQ model. We do not include shortage costs since all demand is satisfied with the basic EOQ model. We do not include the annual item cost either: no quantity discounts are considered in the basic EOQ model, so the annual item cost remains constant regardless of the quantity ordered each time. Given that, our total costs are

$$\text{Total annual cost} = \text{annual ordering costs} + \text{annual holding costs}$$

Problem-Solving Tip When calculating total annual costs, do not round off the number of orders to whole numbers. Although it is true that a partial order cannot be placed, for purposes of comparison we leave the number of orders as a mixed number.

We calculate annual ordering costs by multiplying the number of orders placed per year by the cost to place an order. To find the number of orders placed per year, we divide the annual demand by the quantity ordered.

Suppose annual demand for motherboards at Palm Pilot, the handheld-computer company, is 10,000 units and it currently orders 500 motherboards each time. The number of orders placed per year is 20 (10,000/500). If the cost to place an order is \$75, then the annual ordering cost is \$1500 (20 orders × \$75 ordering cost).

Problem-Solving Tip When solving for Q, it is not necessary to always use annual demand and annual holding costs. If you have demand given in a different time frame (days, weeks, or months), you can use that as long as the holding costs are expressed in the same time frame, that is, daily demand and daily holding costs, or weekly demand and weekly holding costs.

We calculate annual holding costs by multiplying the average inventory level by the annual holding cost per unit. The average inventory is equal to the maximum inventory plus the minimum inventory divided by 2. In the EOQ model, the maximum inventory is Q and the minimum is zero. Therefore, the average inventory level is $Q/2$. For example, if the order quantity is 500 units, the holding cost is \$6 per unit per year, and the annual holding cost is \$1500 (500 units/2 × \$6 per unit). Sometimes the holding cost is given as a percentage, such as 20 percent of the item price. In this case, we multiply the item price by the percentage to determine the annual unit holding costs. For example, if the holding cost is 20 percent of the item price and the item price is \$30, then the annual holding cost is \$6 per unit (\$30 item price × 20 percent holding cost).

The formula for calculating the total relevant annual costs for the basic EOQ model is

$$TC = \left(\frac{D}{Q}S\right) + \left(\frac{Q}{2}H\right)$$

where TC = total annual cost
D = annual demand
Q = quantity to be ordered
H = annual holding cost
S = ordering or setup cost

For our example, the total cost is

$$TC = \left(\frac{10{,}000}{500}\$75\right) + \left(\frac{500}{2}\$6\right)$$

or

$$TC = \$1500 + \$1500 = \$3000$$

Note that the annual ordering costs equal the annual holding costs. This is true when we use the EOQ model without rounding. In addition, with the EOQ model, the minimum total cost always results when the annual ordering costs equal the annual holding costs, as shown in Figure 12-4. Note, too, in Figure 12-4 that as order quantity increases so do holding costs and, at the same time, ordering costs decrease since fewer orders are placed. The total costs, however, are always higher when we use an order quantity other than the EOQ.

Calculating the EOQ

We calculate the economic order quantity (Q) using the following formula:

$$Q = \sqrt{\frac{2DS}{H}}$$

where Q = optimal order quantity
D = annual demand
S = ordering or setup cost
H = holding cost

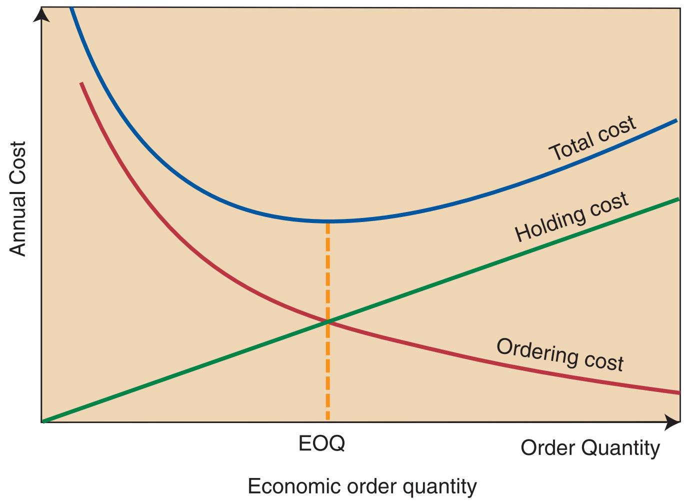


FIGURE 12-4

Holding costs equal ordering costs

EXAMPLE 12.7

Calculating the Economic Order Quantity

Find the economic order quantity and the reorder point, given the following information:

Annual demand (D) = 10,000 units
Ordering cost (S) = $75 per order
Annual holding cost (H) = $6 per unit
Lead time (L) = 5 days
The company operates 250 days per year.

- **Before You Begin:** Identify the appropriate formula to use for calculating the economic order quantity (EOQ) and the reorder point. The formula for the EOQ is

$$Q = \sqrt{\frac{2DS}{H}}$$

and the formula for finding the reorder point is $R = dL$. Remember to make sure that the holding cost is for the same time period as your demand. For example, if demand is annual, then the holding cost must be an annual holding cost per unit. If demand is monthly, then use a monthly holding cost per unit. You also need to convert annual demand into daily demand to use the reorder point formula. Do this by dividing annual demand by the number of days the company operates per year.

- **Solution:**

$$Q = \sqrt{\frac{2 \times 10{,}000 \times \$75}{\$6}} = 500 \text{ units}$$

Daily demand is 40 units per day (10,000 units demanded annually, divided by 250 days of operation).

$$R = 40 \text{ units} \times 5 \text{ days} = 200 \text{ units}$$

The inventory policy for this item is to place a replenishment order for 500 units (Q) when the inventory reaches 200 units (R). The replenishment order will arrive just as the current inventory reaches zero. On the previous page, we calculated total annual cost for this policy ($3000). *The EOQ model always minimizes total annual costs.*

What Happens When a Non-EOQ Order Quantity Is Used? To illustrate what happens to annual inventory costs when we use an order quantity other than the EOQ, let's look at an example with a non-EOQ quantity. Determine the total annual costs for your company if you choose to order 1000 units each time a replenishment order is placed.

$$TC = \left(\frac{10{,}000}{1000}\,\$75\right) + \left(\frac{1000}{2}\,\$6\right) = \$3750$$

The total annual cost for this non-EOQ inventory policy is $3750 compared to $3000 for the EOQ policy. Thus we can say that the *difference* between the EOQ policy and any other policy is a penalty cost incurred by your company for *not* using the EOQ policy.

Economic Production Quantity (EPQ)

The basic EOQ model assumes that the entire replenishment order arrives at one time, but this is not always the case. For example, if we bake four batches each of one-dozen chocolate-chip cookies, our inventory will probably never reach four-dozen cookies. Why? Because we or our friends are sure to eat some of the cookies as soon as we bake them! This means that the maximum inventory level will always be less than the total quantity we produce. If out of every batch of one-dozen cookies, we eat 4 cookies immediately, we will end up with 32 cookies in inventory after baking the four one-dozen batches ((12 baked − 4 used) × 4 batches).

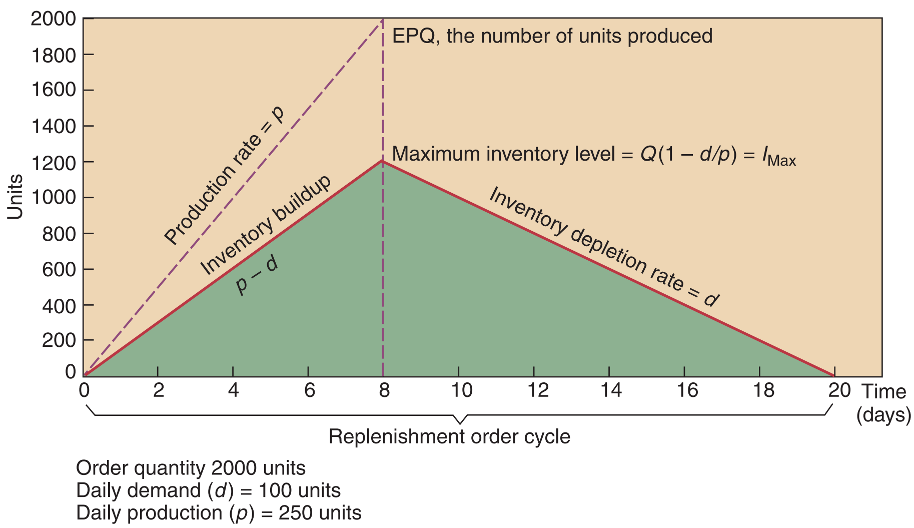
▶ **Economic production quantity (EPQ)** A model that allows for incremental product delivery.

Figure 12-5 shows the **economic production quantity (EPQ)** model. The cycle begins when we start making the product. Each day, we use some of what we make to satisfy immediate demand; we put the remainder in inventory. We make the product until we have completed Q units. At that point, the inventory has reached its maximum level. From this point on, we satisfy demand from the on-hand inventory, depleting it daily. When we reach the reorder point, we order another batch. Our company starts producing the new batch just as we run out of the current inventory.

The EPQ model is appropriate when some of the product we make is used as soon as we make it. In manufacturing, this is typical when a single manufacturing facility produces the parts to build the end product. For example, HP builds deskjet printers using printed circuit boards (PCBs). HP's manufacturing facility builds PCBs in batches; some of these PCBs are assembled into the end product immediately, and the rest are put into inventory.

FIGURE 12-5

The EPQ model



The total cost formula for the EPQ model is

$$TC = \left(\frac{D}{Q}S\right) + \left(\frac{I_{Max}}{2}H\right)$$

where TC = total annual cost
D = annual demand
Q = quantity to be ordered
H = annual holding cost
S = ordering or setup cost

$$I_{Max} = Q\left(1 - \frac{d}{p}\right)$$

where d = average daily demand rate
p = daily production rate

EXAMPLE 12.8

Calculating the Maximum Inventory Level

If HP uses 6 PCBs per day, can produce 20 PCBs, and produces PCBs in batches of 200 units, determine the maximum inventory level.

- **Before You Begin:** Remember that when calculating I_{Max}, your answer will always be less than the economic production quantity (EPQ) since you are using some items as soon as they are completed. You really don't need a formula to compute I_{Max}. In the following example, you are producing a total of 200 PCBs, which takes a total of 10 days to complete (200 units required/20 units produced daily). Each of the 10 days you produce this PCB, you use 6 of the just completed units to satisfy immediate demand and the remaining 14 units go into inventory. Since we do this for 10 straight days, our maximum inventory is 140 units (14 units per day times 10 days). As shown here, you can also use the equation.

- **Solution:**

$$I_{Max} = 200\left(1 - \frac{6}{20}\right) = 140 \text{ units}$$

The production rate must always be greater than the demand rate. Otherwise, a company could never produce enough to satisfy demand and no inventory would be generated. Using the chocolate-chip cookie scenario as an example: it is impossible to eat more than 12 cookies after the batch is baked because no matter how

Will & Deni McIntyre/Stone/Getty Images, Inc.

Making cookies!

much we might *want* to eat more than 12, we must wait for the next batch to be completed.

Although the formula identifies d as daily demand and p as daily production, we can use other time frames for these variables. We can use hourly demand and hourly production, weekly demand and weekly production, monthly demand and monthly production, quarterly demand and quarterly production, or even annual demand and annual production. The important thing to remember is that the time frame must be the same for both demand and production. That way, the ratio always remains the same.

EXAMPLE 12.9

Calculating Ratios

Calculate the ratio of d/p using daily, weekly, and annual demand. Annual demand is 10,000 units and annual production is 25,000 units. The company operates 50 weeks per year, 5 days per week.

- **Before You Begin:** This example is to show you that the most important issue in calculating ratios of demand/production is to use the same time frame. The ratio remains constant whether we use daily demand/daily production, weekly demand/weekly production, or annual demand/annual production. Just make sure that both the demand and production rates are for the same time period

- **Solution:**

When using daily figures,

Average daily demand: d = 10,000 units/250 days = 40 units per day
Daily production: p = 25,000 units/250 = 100 units per day
Therefore, the ratio d/p = 40/100 or 0.4.

When using weekly figures,

Average weekly demand: d = 10,000 units/50 weeks = 200 units per week
Weekly production: p = 25,000 units/50 weeks = 500 units per week
Therefore, the ratio d/p = 200/500 or 0.4.

When using annual figures,

Average annual demand: d = 10,000 units
Annual production: p = 25,000 units
Therefore, the ratio d/p = 10,000/25,000 or 0.4.

Calculating EPQ The formula to calculate the economic production quantity is

$$Q = \sqrt{\frac{2DS}{H\left(1 - \frac{d}{p}\right)}}$$

where D = annual demand in units
S = setup or ordering cost
H = annual holding costs per unit
d = average daily demand rate
p = daily production rate

EXAMPLE 12.10

Calculating EPQ at Ashlee's Beach Chairs

Ashlee's Beach Chairs Company produces upscale beach chairs. Annual demand for the chairs is estimated at 18,000 units. The frames are made in batches before the final assembly process. Ashlee's final assembly department needs frames at a rate of 1500 per month. Ashlee's frame department can produce 2500 frames per month. The setup cost is $800, and the annual holding cost is $18 per unit. The company operates 20 days per month. Lead time is 5 days. Determine the optimal order quantity, the total annual costs, and the reorder point.

• **Before You Begin:** To determine the optimal EPQ, use the formula

$$Q = \sqrt{\frac{2DS}{H\left(1 - \frac{d}{p}\right)}}$$

Remember that the demand and production rates used to calculate the ratio must be in the same time frame (daily, weekly, monthly, quarterly, or annually). To calculate the reorder point, use the formula $R = dL$. Don't forget to transform monthly demand into daily demand to find the reorder point. Reorder points should be found using the easiest numbers possible. For example, if lead time is given as three weeks, then you should find average weekly demand and multiply by the three weeks. If lead time is given in months, use average monthly demand.

• **Solution:**

To determine the total cost, you must calculate the maximum inventory level. To do this you must first calculate the economic production quantity:

$$Q = \sqrt{\frac{2 \times 18{,}000 \times \$800}{\$18\left(1 - \frac{1500}{2500}\right)}} = 2000 \text{ units}$$

Therefore, I_{Max} is

$$I_{\text{Max}} = 2000\left(1 - \frac{1500}{2500}\right) = 800 \text{ units}$$

and the total annual cost is

$$\begin{aligned} TC &= \left(\frac{18{,}000}{2000}\$800\right) + \left(\frac{800}{2}\$18\right) \\ &= \$7200 + \$7200 \\ &= \$14{,}400 \end{aligned}$$

Note that the ordering cost equals the annual holding cost. The reorder point is calculated as $R =$ 75 units $\times$ 5 days $=$ 375 units. Therefore, the inventory policy is to order a quantity of 2000 frames when the inventory reaches 375 units. The total annual cost (excluding item cost) associated with this policy is $14,400.

Compare this policy to Ashlee's current inventory policy of producing in quantities of 1500 units. First, determine the maximum inventory level.

$$I_{\text{Max}} = 1500\left(1 - \frac{1500}{2500}\right) = 600 \text{ units}$$

Therefore, total cost is

$$TC = \left(\frac{18{,}000}{1500}\$800\right) + \left(\frac{600}{2}\$18\right) = \$15{,}000$$

The extra cost or penalty cost associated with Ashlee's current policy is $600 ($15,000 − $14,400).

Perpetual inventory record Provides an up-to-date inventory balance.

When you use the EOQ and/or the EPQ model, you need to know when the inventory level reaches the reorder point. A **perpetual inventory record** provides an up-to-date inventory balance by recording all inventory transactions—items received into inventory or items disbursed from inventory—as they happen.

An alternative to using perpetual inventory records is the two-bin system. In a two-bin system, a quantity equal to demand during replenishment time is held back, often in a second bin. When stock available is depleted, the held-back quantity is made available for use and a replenishment order is placed. Deciding on the right quantity replenishment order is complicated when quantity discounts are available. Let's extend the basic EOQ model to consider quantity discounts.

Quantity Discount Model

Quantity discount model Modifies the EOQ process to consider cases where quantity discounts are available.

The basic EOQ model assumes that no quantity discounts are available. In real life, however, **quantity discounts** are often available, so we need to modify the basic model for these situations. Quantity discounts are price incentives to encourage a company to buy in larger quantities. For example, a supplier charges your company \$7.50 per pound if your company's order is less than 500 pounds. If your order is for 500 to 999 pounds, the price per pound is \$6.90. On orders of 1000 pounds or more, the supplier charges \$6.20 per pound.

Whenever the price per unit is not fixed but varies based on the size of your order, the total annual cost formula for any inventory policy used must include the cost of material, as shown next.

$$TC = \left(\frac{D}{Q}S\right) + \left(\frac{Q}{2}H\right) + CD$$

where D = annual demand in units
Q = order quantity in units
S = ordering or setup cost
H = annual holding cost
C = unit price

EXAMPLE 12.11

Annual Total Costs at Jeannette's Steak House

Jeannette's Steak House currently orders 200 pounds of single-portion filet mignons at a time (a two-week supply). The annual demand for the filets is 5200 pounds. The ordering cost is estimated at \$50. The annual holding cost is 30 percent of the unit price. Jeannette pays \$7.50 per pound for the steaks. Therefore, the annual holding cost rate is \$2.25 (\$7.50 × 0.30). What are the annual total costs?

- **Before You Begin:** In this problem we must include the cost of the steaks as we consider quantity discounts. It is never wrong to include the material costs in the total cost calculation, but we usually omit the material cost unless different replenishment policies result in different material costs. If the material cost is not affected by the policy, then it is a constant and does not need to be included.

- **Solution:**

$$TC = \left(\frac{5200}{200}\$50\right) + \left(\frac{200}{2}\$2.25\right) + (\$7.50 \times 5200) = \$40{,}525$$

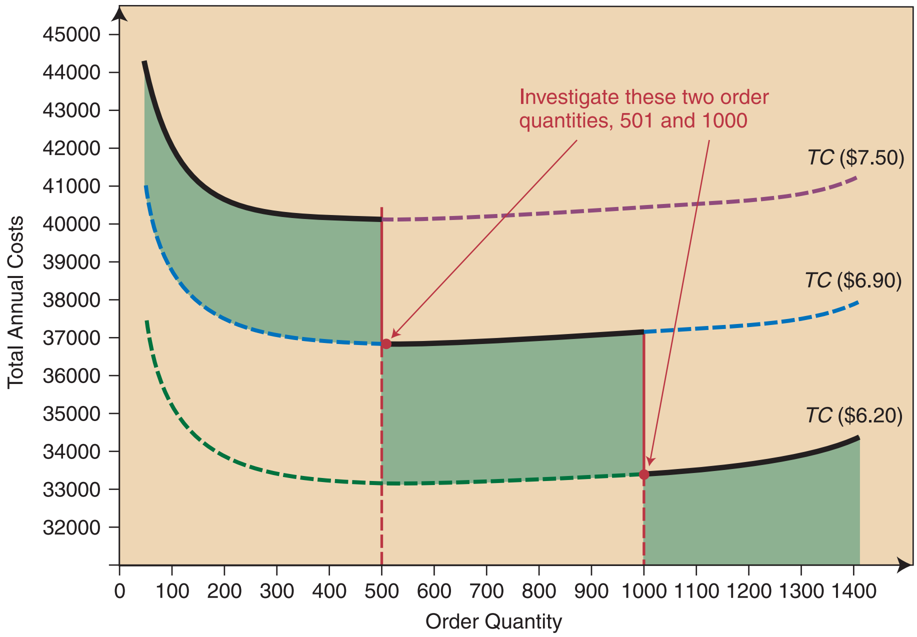


FIGURE 12-6

Quality discount total cost curves

Jeannette's supplier has offered the following price incentives. If Jeannette places an order for 500 or more pounds, the cost per pound is \$6.90. For orders of 1000 pounds or more, the supplier will charge Jeannette \$6.20 per pound. For orders of less than 500 pounds, Jeannette would continue to pay \$7.50 per pound. Now there are three possible prices based on the size of the order. Let's look at how Jeannette can determine the best policy for her business.

Figure 12-6 shows the total annual cost curves for each of the three prices. You can see that the \$7.50 price is only valid when the order quantity falls between 1 and 499 pounds; the \$6.90 price per pound is only valid when the order quantity falls between 500 and 999 pounds; and the \$6.20 price is valid for orders of 1000 or more pounds.

The Quantity Discount Procedure The first step is to calculate the order quantity using the basic EOQ model and the cheapest price available. In our example, Jeannette's cheapest price is \$6.20 per pound. Therefore, the annual holding cost is \$1.86 (that is, \$6.20 $\times$ 0.30), and the EOQ is

$$Q = \sqrt{\frac{2 \times 5200 \times \$50}{\$1.86}} = 528.74 \text{ pounds}$$

Now determine whether the order quantity is feasible. If Jeannette orders this quantity, will she be charged the price used to calculate the EOQ? If Jeannette orders 528.74 pounds, the supplier will charge her \$6.90 per pound rather than the \$6.20 she used in calculating the order quantity. Therefore, this is an infeasible quantity. If it were feasible, we would be done calculating Jeannette's optimal inventory policy. Since the order quantity is infeasible, we calculate the order quantity using the next higher price, \$6.90 per pound.

$$Q = \sqrt{\frac{2 \times 5200 \times \$50}{\$2.07}} = 501.20 \text{ pounds}$$

If Jeannette orders 501 pounds, the supplier charges her $6.90 per pound, which is the same as the price we used in calculating the order quantity. Therefore, this is a feasible order quantity. Once Jeannette finds the feasible quantity, she calculates the total annual costs for this order quantity.

$$TC = \left(\frac{5200}{501}\$50\right) + \left(\frac{501}{2}\$2.07\right) + (\$6.90 \times 5200) = \$36{,}917.50$$

Jeannette compares the total annual cost of this feasible order quantity with the total annual cost of the minimum order quantities necessary to qualify for any prices lower than the price at which she found the feasible solution. For example, to qualify for a price of $6.20 per pound, Jeannette must order a minimum of 1000 pounds at a time. The total annual cost of ordering 1000 pounds at a time is

$$TC = \left(\frac{5200}{1000}\$50\right) + \left(\frac{1000}{2}\$1.86\right) + (\$6.20 \times 5200) = \$33{,}430.00$$

In this case, Jeannette's annual cost is less if she orders 1000 pounds at a time rather than the EOQ quantity of 501 pounds at a time. The optimal inventory policy for Jeannette is to order 1000 pounds at a time.

Note that this assumes Jeannette has adequate storage capacity and can accommodate 1000 pounds at a time. The quantity discount procedure when holding costs are given as a percentage of the unit price is summarized in Table 12-5.

At times, the holding cost can remain constant regardless of the price paid for an item. When the holding cost is a constant dollar amount, there is a common Q. The Q calculated will only be feasible in one of the price ranges. If the Q is in the least expensive price range, that is the optimal order quantity. If the Q is in a higher price range, total costs must be calculated and compared to the total costs of all lower price breaks.

TABLE 12-5

Quantity Discount Procedure

1. Calculate the order quantity using the basic EOQ model and the cheapest price possible.
2. Determine whether the order quantity is feasible. That is, if we order this quantity will the supplier charge us the price we used to determine our order quantity? If this is a feasible order quantity, you are done. Otherwise, go to Step 3.
3. If the EOQ quantity found in Step 1 was infeasible, calculate the EOQ for the next higher price.
4. Check again to determine if this quantity is feasible. If it is not feasible, repeat Step 3. If it is feasible, move on to Step 5.
5. Calculate the total annual costs associated with your feasible order quantity. You must include ordering, holding, and material costs.
6. Calculate the total annual costs associated with buying the minimum quantity required to qualify for any prices that are lower than the price at which the feasible solution was found.
7. Compare the total annual costs of buying these minimum quantities to receive the cheaper price against the cost of the feasible *Q*.
8. Recommend whichever order policy has the lowest total annual cost.

EXAMPLE 12.12

Quantity Discounts with Constant Holding Costs at Valley Grand Health Clinic (VGHC)

VGHC operates its own laboratory on-site. The lab maintains an inventory of test kits for a variety of procedures. VGHC uses 780 A1C kits each year. Ordering costs are \$15 and holding costs are \$3 per kit per year. The new price list indicates that orders of fewer than 73 kits will cost \$60 per kit, 73 through 144 kits will cost \$56 per kit, and orders of more than 144 kits will cost \$53 per kit. Determine the optimal order quantity and the total cost.

- **Before You Begin:** When you have constant holding costs, you only need to calculate a single Q value using the basic EOQ formula:

$$Q = \sqrt{\frac{2DS}{H}}$$

Check to see what price you must pay per unit if this order quantity is used. If it is the cheapest possible price, this is your optimal replenishment order quantity. If cheaper prices are available, calculate the total annual cost if you buy just enough to qualify for the cheaper price. Do this for all prices cheaper than the price you qualified for with the EOQ. Select the policy that has the lowest total costs, making sure that material costs were included.

- **Solution:**

The first step is to calculate the common Q.

$$Q = \sqrt{\frac{2 \times 780 \times \$15}{\$3}} = 88.3\text{, or } 89 \text{ kits}$$

This quantity qualifies for a price of \$56 per kit. Since it is not the lowest possible price, we calculate the total cost at this price and compare it to the total cost at any lower price breaks. The total cost when ordering 89 kits is

$$TC = \left(\frac{780}{89}\$15\right) + \left(\frac{89}{2}\$3\right) + (\$56 \times 780) = \$43{,}944.96$$

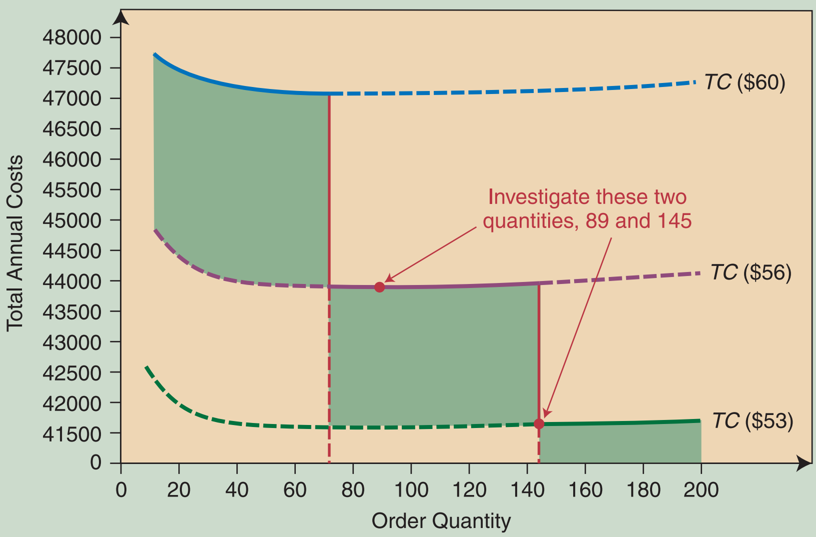
Total cost when ordering 145 kits is

$$TC = \left(\frac{780}{145}\$15\right) + \left(\frac{145}{2}\$3\right) + (\$53 \times 780) = \$41{,}638.19$$

Therefore, the VGHC should order 145 kits at a time since it will save \$2306.77 each year (\$43,944.96 − \$41,638.19). The total annual cost curves are shown in Figure 12-7.

FIGURE 12-7

Quantity discount total annual cost with constant holding cost



WHY COMPANIES DON'T ALWAYS USE THE OPTIMAL ORDER QUANTITY

Even though it can be shown mathematically that not using the optimal EOQ quantity results in additional costs for a company, it is not unusual for companies to order a quantity other than the EOQ.

Some companies do not have known uniform demand. In some cases, companies experience lumpy demand (that is, some periods with significant demand and other periods with no demand). This violates one of the underlying assumptions of the EOQ model. In such cases, it is better to use a period-order quantity (discussed later in this chapter).

Some suppliers have a minimum order quantity that they will sell to a company. This minimum order quantity can be based on how the item is packaged. If the item comes in boxes of 1000, the minimum order for the item becomes 1000 pieces. If you need more than one box, you must order additional boxes. To obtain 4000 pieces, you would order four boxes. Some suppliers are willing to break boxes, but many are not. At other times, the minimum order quantity can be based on how the material is shipped. The minimum order quantity may be what is needed to qualify for a full truckload or full railcar load rate. There are also times when a company may not have sufficient storage capacity to accommodate a large order quantity. When that is the case, companies must order less than the EOQ.

Remember that the EOQ must be checked when quantity discounts are available. The basic model did not allow for discounts, so you must confirm what the optimal order policy should be.

The EOQ policy always provides a benchmark to compare against other policies. It is not wrong not to use the EOQ, but it should be more expensive. You need to justify the additional expenses incurred.

JUSTIFYING SMALLER ORDER QUANTITIES

One of the principles of the just-in-time philosophy, discussed in Chapter 7, is to reduce order quantities ideally down to an order size of one unit. Smaller orders improve customer responsiveness, reduce cycle inventory, reduce work-in-process (WIP) inventory, and reduce inventories of raw materials and purchased components. Since many good things happen with smaller order quantities, we need to understand how companies economically reduce their order quantities.

LINKS TO PRACTICE

Kenworth Trucks
www.kenworth.com


M.L. Sinibaldi/Corbis

Kenworth Trucks, a manufacturer of elite custom-built trucks, leads the industry in operations due largely to the just-in-time effect. Turning out over 35 trucks a day, Kenworth has been able to cut production time from the industry norm of six to eight weeks down to a mere three weeks. Such an outstanding feat is the result of the implementation of several cutting-edge ideas. Most importantly, there is the use of electronic transmission, which allows the plant to receive specifications as soon as a buyer has placed an order and which immediately involves parts suppliers in the details of the order. This synchronization results in supplies going almost directly to the assembly line. With such a fine-tuned operation, it is no wonder Kenworth Trucks is known as the premier of its industry!

Let's use the economic production quantity model to illustrate how companies justify smaller lot sizes.

Understanding the EPQ Factors

Looking at the EPQ formulation, we can see that three variables influence the size of the optimal order quantity. The demand, setup cost, and holding cost are the variables used.

$$Q = \sqrt{\frac{2DS}{H\left(1 - \frac{d}{p}\right)}}$$

where D = annual demand
S = setup cost
H = annual holding cost per unit
d = average daily demand
p = average daily production

To decrease the optimal order quantity, we must reduce the product of the terms under the square root. We can reduce the numerator or increase the denominator. It doesn't make sense for a company to want to increase its holding costs, so we eliminate the idea of increasing the denominator. To reduce the numerator, we can reduce either the annual demand or the setup cost. Most companies are not trying to reduce their annual demand, so we have only one variable left to use: setup cost.

Let's look at an example to see what happens when setup cost is reduced. The Gamma Toy Company has an annual demand of 10,000 units for one of its toys. The daily demand is 50 units. The daily production rate is 75 units. Annual holding cost per unit per period is \$6. Setup cost is estimated to be \$100. When we use these values, the economic production quantity is 1000 units, as shown.

$$Q = \sqrt{\frac{2(10{,}000)100}{6\left(1 - \frac{50}{75}\right)}} = 1000 \text{ units}$$

Now let's look at what happens if we reduce the setup cost from \$100 down to \$25. When we use the new setup cost, the economic production quantity is 500 units, as shown.

$$Q = \sqrt{\frac{2(10{,}000)25}{H\left(1 - \frac{50}{75}\right)}} = 500 \text{ units}$$

Let's compare the total annual costs of these two different lot sizes. When $Q = 1000$ units, the total annual cost is

$$TC = \frac{10{,}000}{1000} \times 100 + \left(\frac{(1000)\left(1 - \frac{50}{75}\right)(6)}{2}\right) = \$2000$$

as opposed to a total cost of \$1000 when using $Q = 500$ units.

$$TC = \frac{10{,}000}{500} \times 25 + \left(\frac{(500)\left(1 - \frac{50}{75}\right)(6)}{2}\right) = \$1000$$

You can see that reducing the setup cost allows us to economically decrease order quantity. If a company fails to reduce its setup costs and just starts producing in smaller order quantities, it will face higher total annual inventory costs.

DETERMINING SAFETY STOCK LEVELS

MKT

Companies are vulnerable to shortages during replenishment lead times, so one function of inventory is to provide safety stock as a cushion for satisfying unexpected customer demand. Remember that you typically place the replenishment order when the inventory level reaches the reorder point. Remember, too, that your company may experience a shortage between the time you place the replenishment order and the time you receive the items you ordered.

When we have no demand uncertainty, we set the reorder point to equal-to-average demand during lead time, or

$$R = dL$$

where R = reorder point in units
d = daily demand in units
L = lead time in days

Therefore, if $d = 20$ units and $L = 10$ days, the reorder point is 200 units. Since we know demand and lead time with certainty, the replenishment order arrives just as the on-hand inventory is depleted.

Suppose your kayak suppliers cannot always keep a firm delivery date because of fluctuation in materials availability at their end. As a result, uncertainty is a condition of your kayaking equipment operation. To support your company's customer service objectives, your policy is to carry safety stock. You add the amount of safety stock carried to the reorder point, and the reorder point becomes

$$R = dL + SS$$

where SS = safety stock in units

For example, if $d = 20$ units, $L = 10$ days, and $SS = 50$ units, the reorder point is 250 units. When your company carries safety stock, it increases the reorder point, as shown in Figure 12-8. The replenishment order is now expected to arrive when the inventory on hand equals the safety stock level rather than zero. If demand is greater than expected, then your customers are satisfied from the safety stock. If demand is less than expected, the replacement inventory arrives before the on-hand inventory reaches the safety stock level. Figure 12-9 shows when the replenishment order will arrive.

How Much Safety Stock?

As safety stock increases, so does the customer service level, thus decreasing the chance of shortage. At the same time, however, holding safety stock requires additional inventory investment. Thus it is important to limit the amount of safety stock your company holds.

▶ **Order-cycle service level** The probability that demand during lead time will not exceed on-hand inventory.

Order-cycle service level is the probability that demand during lead time does not exceed on-hand inventory—that on-hand stock is adequate to meet demand. A service level of 95 percent implies that demand does not exceed supply 95 percent of the time. If your company places 20 orders annually, a 95 percent service level implies that demand will not exceed the on-hand quantity in 19 of the 20 replenishment lead times. We calculate the stockout risk as (1 − the order-cycle service level), or 5 percent in the preceding example.

FIGURE 12-8

How safety stock changes the reorder point

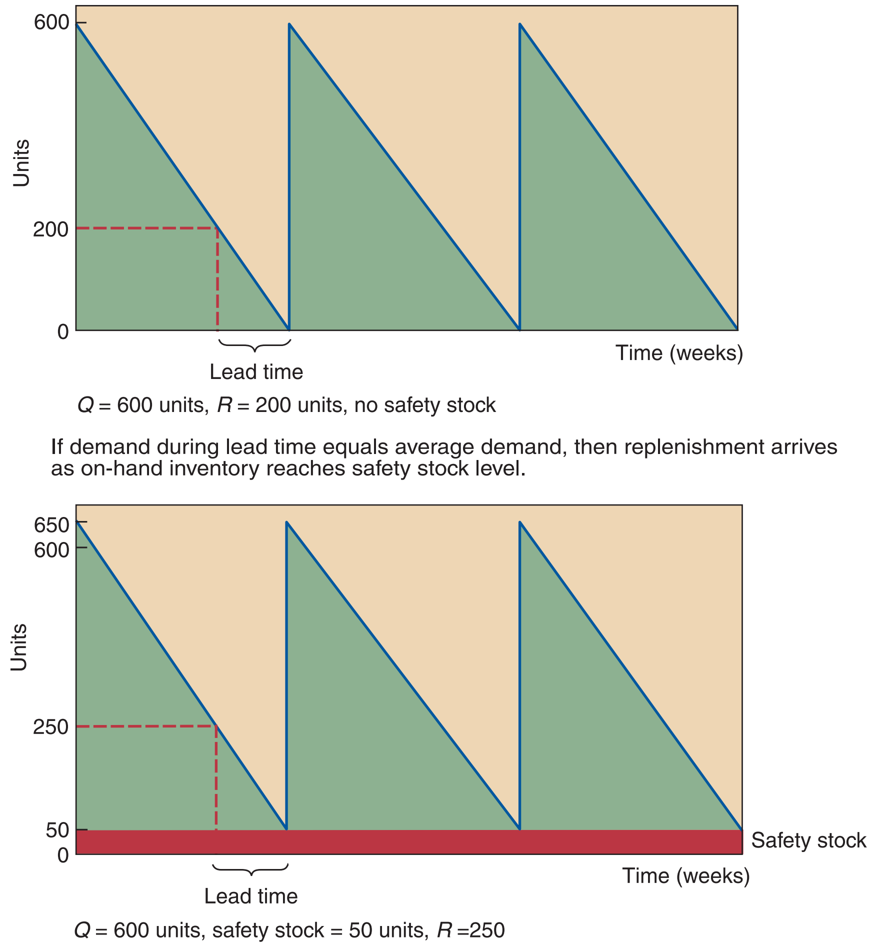
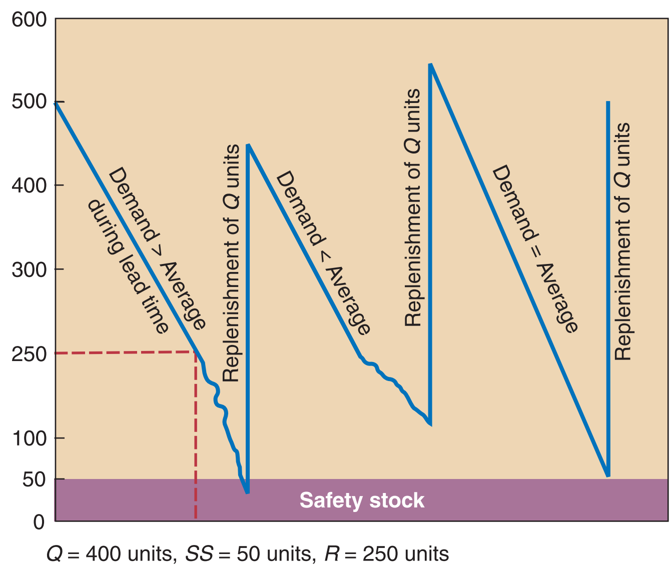


FIGURE 12-9

Demand uncertainty



The amount of safety stock to hold depends on the variability of demand and lead time and the desired order-cycle service level. The safety stock needed to achieve a particular order-cycle service level increases as demand and lead time variability increase. The greater the uncertainty, the more safety stock is needed.

Let's look at a case in which an estimate of demand during lead time and its standard deviation are known. In this case, the formula for calculating safety stock is

$$SS = z\sigma_{dL}$$

where SS = safety stock in units
z = number of standard deviations
σ_{dL} = standard deviation of demand during lead time in units

EXAMPLE 12.13

Nick's Safety Stock

Suppose that the owner of the campus bar, Nick's, has determined that demand for beer during lead time averages 5000 bottles. Nick, the owner, believes the demand during lead time can be described by a normal distribution with a mean of 5000 bottles and a standard deviation of 300 bottles. Nick is willing to accept a stockout risk of approximately 4 percent. Determine the appropriate z value to use. Calculate how much safety stock Nick should hold. Also determine the reorder point.

- **Before You Begin:** To determine how much safety stock, should be held, use the formula $SS = z\sigma_{dL}$. You also need to use Appendix B to determine the appropriate z value. To determine the reorder point, use the formula $R = dL + SS$. Note that safety stock always results in a higher reorder point.

- **Solution:**

Go to Appendix B. To find the appropriate z value associated with the order-cycle service level $(1 - 0.04 = 0.9600)$, you must understand that the appendix shows only positive z values. A z value of 0 represents 0.5000. You need to find the z value that is the difference between the desired service level and a z value of 0 $(0.9600 - 0.5000 = 0.4600)$. Look for the entry closest to 0.4600. If you look at the entry associated with a z value of 1.75, you should see 0.4599, which is as close to 0.4600 as we can get. Therefore, the appropriate z value is 1.75. To determine the appropriate amount of safety stock, do the following calculation:

$$SS = 1.75 \times 300 \text{ bottles} = 525 \text{ bottles of safety stock}$$

The reorder point would now be

$$R = 5000 + 525 = 5525 \text{ bottles}$$

PERIODIC REVIEW SYSTEM

► **Target inventory level (*TI*)** Used in determining order quantity in the periodic review system. Target inventory less on-hand inventory equals order quantity.

With the periodic review system, you determine the quantity of an item your company has on hand at specified, fixed-time intervals (such as every Friday or the last day of every month). You place an order for an amount (Q) equal to the **target inventory level (*TI*)**, minus the quantity on hand (OH), similar to the min-max system. The difference is that with the periodic review system, the time between orders is constant (such as every hour, every day, every week, or every month) with varying quantities ordered. The min-max system varies both the time between orders and the quantities ordered.

An advantage of the periodic review system is that inventory is counted only at specific time intervals. You do not need to monitor the inventory level between review periods. This system also makes sense when you order several different items from a supplier. For example, if your company buys 10 different items from the same supplier, you can place one order for all 10 items rather than 10 individual orders, one for each item.

Potential disadvantages include the varying replenishment levels. First, since you must have sufficient space to store the largest possible order quantity, often you will have excess space when the replenishment orders are smaller. Second, because of varying quantities, you may not be able to qualify for specific quantity discounts.

One result from using the periodic review system is a larger average inventory level. Your company must carry enough inventory to protect against stockout for the replenishment lead time plus the review period. The two major decisions to be made when using the periodic review system concern the time between orders and the target inventory level.

The time between orders (TBO) may be selected for convenience reasons. That is, it may be easier for you to review your inventory at the end of each week and prepare your replenishment order then. An alternative is to base your TBO on the economic order quantity calculation. For example, if you determine that the EOQ = 75 units and that weekly demand is 25 units, it makes sense to place orders every three weeks. You simply divide the EOQ by the average weekly demand.

The target inventory (TI) level is calculated as:

$$TI = d(RP + L) + SS$$

where TI = target inventory level in units
d = average period demand in units (period can be day, week, month, etc.)
RP = review period (in days, weeks, or months)
L = lead time (in days, weeks, or months)
SS = safety stock in units

The safety stock is calculated as

$$SS = z\sigma_{RP+L}$$

where z = number of standard deviations
σ_{RP+L} = standard deviation of demand during review period and lead time and is calculated as

$$\sigma_{RP+L} = \sigma_t\sqrt{RP + L}$$

where σ_t = standard deviation of demand during interval t
RP = review period
L = lead time

To calculate the replenishment order quantity, use the following formula:

$$Q = TI - OH$$

where Q = replenishment order quantity
TI = target inventory level
OH = on-hand quantity

Note that when the lead time is greater than the review period, the on-hand quantity must include any on-order amounts.

EXAMPLE 12.14

Using the Periodic Review System

Gray's Pharmacy uses a periodic review inventory system. Every Friday, the pharmacist reviews her inventory and determines the size of the replenishment order. For example, she knows that demand for 500-mg metformin tablets, a drug for diabetics, is normally distributed with a mean of 6000 tablets each week with a standard deviation of 500 tablets per week. Lead time is three weeks. The desired cycle-service level is 95 percent. There are currently no outstanding orders.

(a) Calculate the required safety stock.
(b) Calculate the target inventory level.
(c) If, when she reviews her inventory of metformin, the pharmacist finds that she currently has 19,000 tablets, calculate the appropriate replenishment order quantity.

- **Before You Begin:** For this problem, you must determine the target inventory level and make a decision as to the replenishment quantity to order. To calculate the target inventory, find the appropriate safety stock level. Use the formula $SS = z\sigma_{RP+L}$. Calculate the target inventory as $TI = d(RP + L + SS)$. After determining the target inventory, calculate the appropriate order size as $Q = TI - OH$.

- **Solution:**

(a) Go to Appendix B, the area under the standardized normal curve, and look for the z value that equates to 95 percent of the area under the curve. Since the appendix only uses positive z values, and they start at 0.50, we need to look for a z value that matches the difference between the desired cycle-service level (0.95) and the starting point of 0.50. So we are looking for a value close to 0.4500. In the appendix we can see that $z = 1.64$ has a value of 0.4495 while $z = 1.65$ has a value of 0.4505. By interpolation, a $z = 1.645$ has a value of exactly 0.4500. Therefore, our desired z value is 1.645.

$$SS = 1.645(\sigma_t\sqrt{RP + L})$$
$$SS = 1.645(500\sqrt{1 + 3}) = 1645 \text{ tablets}$$

(b) The target inventory level is

$$TI = 6000(1 + 3) + 1645 = 25{,}645 \text{ units}$$

(c) If the current inventory of metformin is 19,000 tablets, the pharmacist should order 6645 tablets, or $Q = 25{,}645 - 19{,}000$ tablets.

Comparison of Continuous Review Systems and Periodic Review Systems

The advantages of continuous review systems (CRS) are the disadvantages of periodic review systems (PRS). For instance, a CRS has no set review periods. This lack of specified review periods means that less inventory is needed to protect against stockouts.

With a PRS, enough inventory must be carried to cover both the lead time and the review period. Since a CRS has no review period, it has a smaller average inventory investment. On the other hand, a CRS means significantly more work because the inventory balances are updated after each transaction rather than periodically. A PRS means less work because inventory balances are only reviewed and updated periodically. So a PRS makes it easier to consolidate orders from a single supplier because you

can review all of those items at the same time interval, whereas the CRS is designed to handle items individually.

In general, companies use CRS for items that are expensive and/or critical to the company because CRS more closely monitors these items and reduces inventory investment. Companies typically use both systems depending on the value and criticality of the items to be monitored.

THE SINGLE-PERIOD INVENTORY MODEL

Some finished goods inventories have very short selling seasons. Items such as holiday decorations, Christmas trees, long-stemmed red roses, newspapers, and magazines are good examples. These products typically have a high value for a relatively short period; then the value diminishes dramatically to either zero or some minimum salvage value. For example, week-old newspapers are inexpensive compared to newspapers offering fresh news. The question is how many of these products you should order to maximize your expected profit.

The **single-period model** is designed for products that share the following characteristics:

▶ **Single-period model** Designed for use with products that are highly perishable.

MKT

- They are sold at their regular price only during a single time period.
- Demand for these products is highly variable but follows a known probability distribution.
- Salvage value of these products is less than their original cost, so you lose money when they are sold for their salvage value.

The objective is to balance the gross profit generated by the sale of a unit with the cost incurred for each unit that is not sold until after the primary selling period has elapsed. When demand follows a discrete probability distribution, we can solve the problem using an expected value matrix.

©AP/Wide World Photos

Christmas trees for sale.

EXAMPLE 12.15

Walk for Diabetes

Rick Jones is chairman of this year's Walk for Diabetes event. Each year, the organizers of the event typically have commemorative T-shirts available for purchase by the entrants in the walk. Rick needs to order the shirts well in advance of the actual event. He must place his order in multiples of 10 (60, 70, 80, etc.). Based on past walks, the organizers have determined that the probability of selling different quantities of T-shirts in a given year is as follows:

Demand (shirts)	Probability
80	0.20
90	0.25
100	0.30
110	0.15
120	0.10

Rick plans to sell the T-shirts for \$20 each. He pays his supplier \$8 for each shirt and can sell any unsold shirts for rags at \$2 each. Determine how many T-shirts Rick should order to maximize his expected profits.

• **Before You Begin:** In this problem, you need to determine how many T-shirts to order for the event. If you order too many, you will have leftover shirts with little value. If you don't order enough, you forgo achieving the profit associated with each shirt plus creating some customer ill will. The easiest way to approach this decision is to develop a payoff table to calculate expected profit with each possible order quantity.

• **Solution:**

Based on the information provided, develop a payoff table to determine expected profit with each possible order quantity. Calculate net profit for each combination of order quantity and demand as shown next.

Payoff Table

Probability of occurrence	0.20	0.25	0.30	0.15	0.10	
Customer demand (shirts)	80	90	100	110	120	
Number of Shirts Ordered						**Expected Profit**
80	\$960	\$ 960	\$ 960	\$ 960	\$ 960	\$ 960
90	\$900	\$1080	\$1080	\$1080	\$1080	\$1044
100	\$840	\$1020	\$1200	\$1200	\$1200	\$1083
110	\$780	\$ 960	\$1140	\$1320	\$1320	\$1068
120	\$720	\$ 900	\$1080	\$1260	\$1440	\$1026

The numbers in the payoff table are calculated based on what happened. The three possible outcomes are: (1) the number of shirts ordered equals the number of shirts demanded, (2) the number of shirts ordered is greater than the number of shirts demanded, and (3) the number of shirts ordered is less than the number of shirts demanded. To find the payoff when supply equals demand,

$$\text{Payoff} = \text{demand}(\text{selling price} - \text{unit cost})$$

In our example, look at what happens when 100 T-shirts are bought and 100 T-shirts are sold.

$$\text{Payoff} = 100(\$20 - \$8) = \$1200$$

When the number of shirts ordered exceeds demand, the payoff is calculated as

$$\text{Payoff} = (\text{number of items demanded}) \times (\text{selling price} - \text{item cost}) - ((\text{items ordered} - \text{items demanded}) \times (\text{item cost} - \text{item salvage value}))$$

If 100 T-shirts are ordered and demand is for only 80 shirts, the payoff is

$$\text{Payoff} = 80(\$20 - \$8) - ((100 - 80) \times (\$8 - \$2)) = \$840$$

When the number of shirts ordered is less than demand, the payoff is calculated as

$$\text{Payoff} = \text{number of items ordered} \times (\text{selling price} - \text{item cost})$$

Returning to the example, determine the payoff when 100 T-shirts are ordered but 120 shirts are demanded.

$$\text{Payoff} = 100(\$20 - \$8) = \$1200$$

After we calculate the payoffs for each combination, we can determine the expected profit for each order quantity. We do this by multiplying the payoff for an order quantity by the probability for each level of demand. For example, we calculate the payoff for ordering 100 shirts, $1083, as

$$(\$840 \times 0.20) + (\$1020 \times 0.25) + (\$1200 \times 0.30) + (\$1200 \times 0.15) + (\$1200 \times 0.10)$$

Once we generate the expected profit for each of the possible order quantities, we select the order quantity with the highest expected profit. In our case, Rick should order 100 shirts since doing so has an expected profit of $1083.

INVENTORY MANAGEMENT WITHIN OM: HOW IT ALL FITS TOGETHER

Inventory management provides the materials and supplies needed to support actual manufacturing or service operations. A product cannot be built unless the required material is available. Inventory replenishment policies guide the master production scheduler when determining which jobs and what quantity should be scheduled (Supplement D). The master production schedule inserted into the material requirements planning (MRP) system generates the replenishment orders. This output is used to guide purchasing in terms of the frequency and size of orders. Too much inventory is costly to the organization, yet too little can create major inefficiencies.

Inventory record accuracy is especially critical for MRP users. MRP relies on inventory records to process material requirements, so inaccurate records make the MRP output worthless. This, in turn, can cause manufacturing to shut down and/or miss a deadline.

Inventory management policies also affect the layout of the facility. A policy of small lot sizes and frequent shipments reduces the space needed to store materials (Chapter 7). Point-of-delivery placement of inventory affects the size of work centers. Inventory management also affects throughput time. As a facility increases its work-in-process, throughput times increase. Longer throughput times reduce an organization's ability to respond quickly to changing customer demands (Chapter 4).

Good inventory management assures continuous supply and minimizes inventory investment while achieving customer service objectives.

INVENTORY MANAGEMENT ACROSS THE ORGANIZATION

Inventory management policies affect functional areas throughout a company. Let's consider why individual functional areas are concerned with inventory management policies.

Accounting is concerned because of the cost implications of inventory, such as the holding costs incurred, the capital needed to invest in inventory, and projected cash flow budgets. Accounting is concerned with all types of inventory.

Marketing is concerned because stocking decisions affect the level of customer service provided. Marketing's primary focus is finished goods inventory, where the goods are held within the distribution system, the response time to satisfy customers, and safety stock levels.

Information systems is involved because a system to track and control inventories is needed, especially when perpetual inventory records are used. Given the large number of SKUs and a high volume of inventory transactions, manual processing is impractical for most companies, so a computerized information system is essential.

Purchasing's workload is directly affected by inventory policies. Policies regarding order frequency, order volume, acceptable suppliers, and inventory investment determine the number of purchases made. Purchasing is concerned primarily with buying raw materials, components, and subassemblies.

Manufacturing's cost efficiency can be affected by inventory decisions. If insufficient material is available, either because items are not ordered on time or not ordered in the right quantities, manufacturing efficiency decreases and unit costs increase. Unit costs can also increase when too much material is ordered or when it is ordered too soon.

As you can see, inventory decisions affect many functional areas in a company and may involve input from management in these areas. In addition, inventory decisions have a significant impact on the company's profitability.

Who makes aggregate inventory decisions? Typically, it is the materials manager. This person is evaluated based on customer service levels achieved and inventory turnover. For individual finished goods products, the master scheduler makes decisions about how much of a particular item to produce and how much to keep in inventory. A master scheduler is evaluated based on customer service levels and manufacturing efficiency.

For raw materials, components, and subassemblies, inventory planners, material planners, or controllers make decisions about when to place replenishment orders, either for in-house manufacturing or for external purchasing. Planners and controllers are typically evaluated according to customer service levels and inventory investment.

THE SUPPLY CHAIN LINK

Inventory management deals with economically based item-replenishment policies, safety stock levels, and the appropriate review system for use within a supply chain. Inventory flows from the suppliers to the manufacturers to the distributors. Inventory management provides an understanding of the total costs of inventory as well as the customer service ramifications of specific policies. By themselves, uncoordinated replenishment policies can cause the bullwhip effect (discussed in Chapter 4) in the supply chain. Vendor-managed inventory is one approach committed to improving service levels while reducing inventory investment in the supply chain. A policy of making demand information available (point-of-sale information) to all members of the supply chain reduces demand uncertainty and allows a company to achieve its desired customer service levels with a smaller inventory investment. Inventory management is a key component of effective supply chain performance.

Chapter Highlights

1. Raw materials, purchased components, work-in-process (WIP), finished goods, distribution inventory and maintenance, repair and operating supplies are all types of inventory. Inventories have several uses: anticipation inventory is built before it is needed; fluctuation stock provides a cushion against uncertain demand; cycle stock is a result of the company's ordering quantity; transportation inventory includes items in transit; speculative inventory is a buildup to protect against some future event; and MRO inventory supports daily operations.

2. The objectives of inventory management are to provide the desired level of customer service, to allow cost-efficient operations, and to minimize inventory investment. Customer service can be measured in several ways, including as a percentage of orders shipped on schedule, a percentage of line items shipped on schedule, a percentage of dollar volume shipped on schedule, or idle time due to material and component shortages. Cost-efficient operations are achieved by using inventory as buffer stocks, allowing a stable year-round workforce, and spreading the setup cost over a larger number of units.

3. Inventory investment is measured in inventory turnover and/or level of supply. Inventory performance is calculated as inventory turnover or weeks, days, or hours of supply.

4. Relevant inventory costs include item costs, holding costs, ordering costs, and shortage costs. Holding costs include capital costs, storage costs, and risk costs. Ordering costs are fixed costs for placing an order or performing a setup. Shortage costs include costs related to additional paperwork, additional shipping expense, and the intangible cost of lost customer goodwill.

5. The ABC classification system allows a company to assign the appropriate level of control and frequency of review of an item based on its annual dollar volume.

6. Cycle counting is a method for maintaining accurate inventory records. Determining what and when to count are the major decisions.

7. Retailers, wholesalers, and food service organizations use tangible inventory even though they are service organizations. Proper inventory control and management for these organizations often is the difference between a profit and loss. Since the items are often desirable, organizations must strive to reduce the amount of theft by customers and employees. Magnetic strips, security devices, and surveillance systems are all means of reducing inventory loss.

8. Lot-for-lot, fixed-order quantity, min-max systems, order *n* periods, periodic review systems, EOQ models, quantity discount models, and single-period models can be used to determine order quantities.

9. Ordering decisions can be improved by analyzing total costs of an inventory policy. Total costs include ordering cost, holding cost, and material cost.

10. Practical considerations can cause a company to not use the optimal order quantity, that is, minimum order requirements.

11. Smaller lot sizes give a company flexibility and shorter response times. The key to reducing order quantities is to reduce ordering or setup costs.

12. Calculating the appropriate safety stock policy enables companies to satisfy their customer service objectives at minimum cost. The desired customer service level determines the appropriate z value.

13. Inventory decisions about perishable products (like newspapers) can be made using the single-period inventory model. The expected payoff is calculated to assist the quantity decision.

Key Terms

raw materials 431
components 431
work-in-process (WIP) 432
finished goods 432
distribution inventory 432
anticipation inventory 432
fluctuation inventory 432
lot-size inventory 432
transportation inventory 432
speculative inventory 433
maintenance, repair, and operating inventory (MRO) 433
customer service 434
percentage of orders shipped on schedule 434
percentage of line items shipped on schedule 435
percentage of dollar volume shipped on schedule 435
setup cost 436
inventory turnover 436
weeks of supply 436
item cost 438
holding costs 438
capital costs 438
storage costs 439
risk costs 439
ordering costs 440
shortage costs 440
back order 440
lost sale 440
Pareto's law 440
ABC classification 440
continuous review system 442
periodic review system 443
two-bin system 443

Formula Review

1. Calculating average transportation inventory (ATI):

$$ATI = \frac{tD}{365}$$

where t = transit time in days and D = annual demand in units.

2. Calculating inventory turnover and periods of supply:

$$\text{Inventory turnover} = \frac{\text{annual cost of goods sold}}{\text{average inventory in dollars}}$$

$$\text{Weeks of supply} = \frac{\text{average inventory on hand in dollars}}{\text{average weekly usage in dollars}}$$

$$\text{Days of supply} = \frac{\text{average inventory on hand in dollars}}{\text{average daily usage in dollars}}$$

3. Calculating target inventory (TI):

$$TI = d(RP + L) + SS$$

where d = average daily demand, RP = review period in days, and SS = safety stock.

4. Calculating safety stock in a periodic review model:

$$SS = z\sigma_{RP+L}$$

Standard deviation of demand during review period and lead time:

$$\sigma_{RP+L} = \sigma_t\sqrt{RP + L}$$

5. Calculating reorder point without safety stock:

$$R = dL$$

where d = average daily demand and L = lead time in days.

6. Calculating the economic order quantity (EOQ):

$$Q = \sqrt{\frac{2DS}{H}}$$

where D = annual demand, S = ordering cost, and H = holding cost.

7. Calculating total costs:

$$TC = \left(\frac{D}{Q}S\right) + \left(\frac{Q}{2}H\right)$$

8. Calculating the economic production quantity (EPQ):

$$Q = \sqrt{\frac{2DS}{H\left(1 - \frac{d}{p}\right)}}$$

9. Calculating total costs:

$$TC = \left(\frac{D}{Q}S\right) + \left(\frac{I_{\text{Max}}}{2}H\right)$$

where I_{Max} is the maximum inventory level.

10. Calculating I_{Max}:

$$I_{\text{Max}} = Q\left(1 - \frac{d}{p}\right)$$

where d = daily demand and p = daily production rate.

11. Calculating total costs for quantity discount comparisons:

$$TC = \left(\frac{D}{Q}S\right) + \left(\frac{Q}{2}H\right) + CD$$

where C = price per unit.

12. Calculating amount of safety stock:

$$SS = z\sigma_{dL}$$

where SS = safety stock, z = number of standard deviations, and σ_{dL} = standard deviation of demand during lead time in units.

Solved Problems

(See student companion site for Excel template.)

• Problem 1

Tacky Souvenirs sells lovely handmade tablecloths at its island store. These tablecloths cost Tacky \$15 each. Customers want to buy the tablecloths at a rate of 240 per week. The company operates 52 weeks per year. Tacky, the owner, estimates his ordering cost at \$50. Annual holding costs are 20 percent of the unit cost. Lead time is 2 weeks. Using the information given,

(a) Calculate the economic order quantity.
(b) Calculate the total annual costs using the EOQ.
(c) Determine the reorder point.

• *Before You Begin:*

To calculate the economic order quantity, you use the formula

$$Q = \sqrt{\frac{2DS}{H}}$$

Remember that the demand information and the holding cost must be for the same time frame. That is, if you use annual demand, you must use an annual holding cost. Once you have calculated the EOQ, you calculate total annual costs with the formula

$$TC = \left(\frac{D}{Q}S\right) + \left(\frac{Q}{2}H\right)$$

To find the reorder point, use the formula: $R = dL$. Remember that demand must be in the same time frame as is given for lead time. For example, if lead time is given as three weeks, then use weekly demand. If lead time is given in days, use daily demand.

• *Solution*

(a) First, calculate the annual demand and the annual holding cost.

$$\begin{aligned}\text{Annual demand} &= (52 \text{ weeks} \times 240 \text{ units per week})\\ &= 12{,}480 \text{ units}\end{aligned}$$

$$\begin{aligned}\text{Annual holding cost} &= (0.20 \times \$15)\\ &= \$3.00 \text{ per unit per year}\end{aligned}$$

	A	B	C
1			
2	**Tacky Souvenirs**		
3			
4	**Problem Inputs**		
5	Weekly Demand	240	
6	Operating Weeks per year	52	B7: =B5*B6
7	Annual Demand (units)	12480	
8			
9	Ordering Cost	\$50.00	
10			
11	Annual Holding Cost (%)	20.0%	
12	Unit Cost	\$15.00	B13: =B12*B11
13	Annual Holding Cost (\$/unit)	\$3.00	
14			
15	Lead Time (weeks)	2	
16			
17	**Calculations and Solution**		B18: =SQRT((2*B7*B9)/B13)
18	EOQ (exact calculation)	644.98062	B19: =ROUND(B18,0)
19	EOQ (rounded to nearest integer)	**645**	B20: =(B7/B19)*B9
20	Annual Ordering Costs	\$967.44	B21: =(B19/2)*B13
21	Annual Holding Costs	\$967.50	B22: =B20+B21
22	Total Annual Costs	**\$1,934.94**	B23: =B5*B15
23	Reorder Point (units)	**480**	

Now calculate the economic order quantity as shown in the spreadsheet.

$$Q = \sqrt{\frac{2 \times 12480 \times \$50}{\$3}} = 644.98, \text{ or } 645 \text{ tablecloths}$$

Examine the spreadsheet to see how you can solve EOQ problems using a spreadsheet. Note that you can use weekly demand since the lead time is given in weekly increments. Just make sure that the average demand time frame matches the time frame used with lead time.

(b) The total costs are

$$TC = \left(\frac{12480}{645} \$50\right) + \left(\frac{645}{2} \$3\right) = \$1934.94$$

(c) The reorder point is

$$R = 240 \text{ units} \times 2 \text{ weeks} = 480 \text{ units}$$

• Problem 2

Jack's Packs manufactures backpacks made from microfabrics. The cutting department prepares the material for use by the backpack stitching department. The cutting department can cut enough material to make 200 backpacks per day. The backpack stitching department produces 90 backpacks per day. Annual demand for the product is 22,500 units. The company operates 250 days per year. Estimated setup cost is $60. Annual holding cost is $6 per backpack.

(a) Calculate the economic production quantity for the cutting department.
(b) Calculate the total annual costs for the EPQ.

• *Before You Begin:*

For this problem, calculate the EPQ. We use a modified version of the EOQ formula since we have relaxed the assumption regarding all of the items being delivered at one time. With the EPQ model, units are produced daily. Some are used immediately to satisfy demand, while the other units are put into inventory. The appropriate formula is

$$Q = \sqrt{\frac{2DS}{H\left(1 - \frac{d}{p}\right)}}$$

Remember that the ratio d/p does not have to be daily demand divided by daily production. You need only use figures for the same time frame. The ratio of annual demand divided by annual production is equivalent to the daily demand divided by daily production. You also should check to be sure that the demand rate is smaller than the production rate. Otherwise, you can never produce enough to satisfy demand. When calculating total costs, make sure that you determine the maximum inventory level when assessing holding costs.

• *Solution*

(a) First, calculate the EPQ as follows:

$$Q = \sqrt{\frac{2 \times 22{,}500 \times \$60}{\$6\left(1 - \frac{90}{200}\right)}} = 904.53, \text{ or } 905 \text{ backpacks}$$

(b) To calculate total costs, determine the maximum inventory level as follows:

$$I_{\text{Max}} = 905\left(1 - \frac{90}{200}\right) = 497.75, \text{ or } 498 \text{ backpacks}$$

Now that you have determined the maximum inventory level, calculate total costs:

$$TC = \left(\frac{22{,}500}{905} \$60\right) + \left(\frac{498}{2} \$6\right) = \$2985.71$$

• Problem 3

Ye Olde Shoe Repaire has customers requesting leather soles throughout the year. The owner, Warren, buys these soles from The Leather Company (TLC) at a price of $8 per pair. In an effort to improve profitability by selling in greater quantities, the sales rep for TLC has made the following offer to Ye Olde Shoe Repaire: If Warren orders from 1 to 50 pairs at a time, the cost per pair is $8.00. If the order is between 51 and 100 pairs at a time, the cost is $7.60. On orders for more than 100 pairs at a time, the cost per pair is $7.40. The owner estimates annual demand to be 625 pairs of soles. Holding costs are 20 percent of unit price. The cost to place an order is $10. Determine the most cost-effective ordering policy for Ye Olde Shoe Repaire.

• *Before You Begin:*

This is a quantity discount problem with proportional holding costs. You begin by calculating the EOQ for the least expensive unit price. Check to see if this quantity is feasible. Feasibility occurs when you can order the EOQ quantity and pay the unit price that was used in your calculation. For example, if the EOQ turns out to be 92 pairs of leather soles and you used a unit price of $7.40 per pair, you need to check to see whether or not you will be charged $7.40 per pair if you place an order for 92 pairs. If the initial price assumption does not match what you would actually pay, then the quantity is infeasible. Once you find a feasible quantity, calculate the total annual costs for that policy, including the annual material costs. You must also calculate the total costs associated with ordering just enough units to qualify for any

cheaper prices available. For example, if the feasible quantity occurs with a cost of \$7.60 per pair and you know that if you buy 100 pairs at a time you qualify for a unit price of \$7.40, you calculate the total annual cost assuming that you would order just enough (100 pairs) to qualify for the lower unit price. You must do this for all prices lower than the price of the feasible EOQ. Your best policy is based on the total annual costs.

• *Solution*

(a) First, we need to calculate the EOQ at the lowest price offered. The annual holding cost is 20 percent of the unit cost, or \$1.48—that is, \$7.40 times 20 percent.

$$Q = \sqrt{\frac{2 \times 625 \times \$10}{\$1.48}} = 91.9\text{, or } 92 \text{ pairs}$$

Since this order quantity does not match the unit price used to calculate the EOQ, this answer is infeasible. This means if we place an order for 92 pairs, we are charged \$7.60 per pair rather than the \$7.40 we used in calculating the EOQ.

(b) Since the first Q is infeasible, we calculate the EOQ for the next higher price. Make sure to calculate the new annual holding cost, 20 percent of \$7.60, or \$1.52.

$$Q = \sqrt{\frac{2 \times 625 \times \$10}{\$1.52}} = 90.68\text{, or } 91 \text{ pairs}$$

If we place an order for 91 pairs, we will be charged \$7.60 per pair, which is the price we used to calculate this EOQ. Therefore, this is a feasible order quantity. We are ready to calculate the total annual cost for this policy:

$$TC = \left(\frac{625}{91}\$10\right) + \left(\frac{91}{2}\$1.52\right) + (\$7.60 \times 625)$$
$$= \$4887.84$$

Since the feasible solution was not at the lowest price, we must now compute the total cost of any cheaper price, assuming that we order just enough to qualify for the cheaper price. This means we need to order 101 pairs to qualify for the \$7.40 price. The total cost of this policy is

$$TC = \left(\frac{625}{101}\$10\right) + \left(\frac{101}{2}\$1.48\right) + (\$7.40 \times 625)$$
$$= \$4761.62$$

Since the total annual cost of ordering 101 pairs at a time is less expensive, Ye Olde Shoe Repaire should order 101 pairs each time leather soles are needed.

• Problem 4

Frank's Ribs knows that the demand during lead time for his world-famous ribs is described by a normal distribution with a mean of 1000 pounds and a standard deviation of 100 pounds. Frank is willing to accept a stockout risk of approximately 2 percent.

(a) Determine the appropriate z value.

(b) Calculate how much safety stock Frank should hold.

• *Before You Begin:*

In this problem, you need to find out how much safety stock should be held. First, use Appendix B to determine the z value for the desired safety stock level. Then, using the formula $SS = z\sigma_{dL}$, calculate the required safety stock.

• *Solution*

(a) Go to Appendix B. You need to find the z value associated with 0.4800, which is the difference between the desired service level, 0.9800, and the z value of 0, 0.5000. Looking at the entry for $z = 2.05$, you should see 0.4798, which is as close to 0.4800 as we can get. Therefore, the appropriate z value is 2.05.

(b) To determine the amount of safety stock Frank should hold, multiply the z value by the standard deviation:

$$SS = 2.05 \times 100 \text{ pounds} = 205 \text{ pounds}$$

Frank should hold 205 pounds of ribs in safety stock.

• Problem 5

Peter sells programs at State University's home football games. Peter must buy the programs before the game in multiples of 100 (2000, 2100, 2200, etc.). Peter has determined that the probability of selling different quantities of programs at a given game is as follows:

Demand for Programs	Probability of Demand
2000	0.10
2100	0.20
2200	0.40
2300	0.20
2400	0.10

Peter plans to sell the programs for \$4 each. He pays \$2.50 for each program and there is no salvage value. Determine how many programs Peter should buy to maximize his profit.

• *Before You Begin:*

For this problem, we are only able to make a single purchase. Determine which order quantity has the highest expected payoff. Develop a payoff table to show the expected value from each order quantity.

• *Solution*

Based on the information given, we developed a payoff table to determine the expected profit for each possible order quantity. Net profit for each combination or order quantity and demand are calculated as shown. The order quantity with the highest expected profit is 2200 programs. Peter should order 2200 programs.

	Probability of Occurrence					
	0.10	0.20	0.40	0.20	0.10	
Actual customer demand (programs)	2000	2100	2200	2300	2400	
Number of Programs Ordered						**Expected Profit**
2000	$3000	$3000	$3000	$3000	$3000	$3000
2100	$2750	$3150	$3150	$3150	$3150	$3110
2200	$2500	$2900	$3300	$3300	$3300	$3140
2300	$2250	$2650	$3050	$3450	$3450	$3010
2400	$2000	$2400	$2800	$3200	$3600	$2800

Discussion Questions

1. Visit a local business and identify the different types of inventory used.
2. After visiting a local business, explain the different functions of its inventory.
3. Explain the objectives of inventory management at the local business.
4. Describe how the objectives of inventory management can be measured.
5. Explain the different methods for measuring customer service.
6. Compare the two techniques, inventory turnover and weeks of supply.
7. Describe the relevant costs associated with inventory policies.
8. Explain what is included in the annual holding cost.
9. Describe what is included in ordering or setup costs.
10. Describe what is included in shortage costs.
11. Explain the assumptions of the EOQ model.
12. Describe techniques for determining order quantities other than the EOQ or EPQ.
13. Describe how changes in the demand, ordering cost, or holding cost affect the EOQ.
14. Explain how a company can justify smaller order quantities.
15. Explain what safety stock is for.
16. Explain how safety stock affects the reorder point.
17. Describe the type of products that require a single-period model.
18. Explain the basic concept of ABC analysis.
19. Explain the concept of perpetual review.
20. Explain how two-bin systems work.

Problems

1. Elyssa's Elegant Eveningwear (EEE) needs to ship finished goods from its manufacturing facility to its distribution warehouse. Annual demand for EEE is 2400 gowns. EEE can ship the gowns via regular parcel service (3 days transit time), premium parcel service (1 day transit time), or via public carrier (7 days transit time). Calculate the average annual transportation inventory for each alternative.

2. Yasuko's Art Emporium (YAE) ships art from its studio located in the Far East to its distribution center located on the West Coast of the United States. YAE can send the art either via transoceanic ship freight service (15 days transit) or by air freight (2 days transit time). YAE ships 18,000 pieces of art annually.
   (a) Calculate the average annual transportation inventory when sending the art via transoceanic ship freight service.
   (b) Calculate the average annual transportation inventory when sending the art via air freight.
   (c) What additional information is needed to compare the two alternatives?

3. Joe, the owner of Genuine Reproductions (GR), a company that manufactures reproduction furniture, is interested in measuring inventory effectiveness. Last year the cost of goods sold at GR was $3,000,000. The average inventory in dollars was $250,000.
   (a) Calculate the inventory turnover for GR.
   (b) Calculate the weeks of supply. Assume 52 weeks per year.
   (c) Calculate the days of supply. Assume that GR operates 5 days per week.

4. Genuine Reproductions (GR) plans on increasing next year's sales by 20 percent while maintaining its same average inventory in dollars of $250,000.
   (a) Calculate the expected inventory turnover for next year.
   (b) Calculate the expected weeks of supply.

5. What is the inventory turnover for Genuine Reproductions from Problems 3 and 4 if sales actually increase 20 percent but the average inventory rises to $325,000?

6. Frederick's Farm Factory (FFF) currently maintains an average inventory valued at $3,400,000. The company estimates its capital cost at 10 percent, its storage cost at 4.5 percent, and its risk cost at 6 percent.

(a) Calculate the annual holding cost rate for FFF.
(b) Calculate the total annual holding costs for FFF.

7. The Federal Reserve Board has just increased the interest rate. FFF in Problem 6 now has to pay 12 percent for its capital. Calculate the impact on total annual holding costs for FFF.

8. A technology problem has rendered some of the inventory at FFF (Problem 6) obsolete. FFF estimates that the risk cost of its inventory is now 10 percent.

(a) Calculate the new annual holding cost rate.
(b) Calculate the new total annual holding costs for FFF.

9. Custom Computers, Inc. assembles custom home computer systems. The heat sinks needed are bought for $12 each and are ordered in quantities of 1300 units. Annual demand is 5200 heat sinks, the annual inventory holding cost rate is $3 per unit, and the cost to place an order is estimated to be $50. Calculate the following:

(a) Average inventory level
(b) The number of orders placed per year
(c) The total annual inventory holding cost
(d) The total annual ordering cost
(e) The total annual cost

10. Custom Computers, Inc. from Problem 9 is considering a new ordering policy. The new order quantity would be 650 heat sinks. Recalculate Problem 9, parts (a) through (e), and compare results.

11. Bill Maze, recently hired by Custom Computers, Inc., has suggested using the economic order quantity for the heat sinks. Using the information in Problem 9, calculate the following:

(a) Economic order quantity
(b) Average inventory level
(c) The number of orders placed per year
(d) The total annual ordering cost
(e) The total annual holding cost
(f) The total annual cost

Compare these results with the costs calculated in Problems 9 and 10.

12. A local nursery, Greens, uses 1560 bags of plant food annually. Greens works 52 weeks per year. It costs $10 to place an order for plant food. The annual holding cost rate is $5 per bag. Lead time is one week.

(a) Calculate the economic order quantity.
(b) Calculate the total annual costs.
(c) Determine the reorder point.

13. Rapid Grower, the supplier of plant food for Greens in Problem 12, has offered the following quantity discounts. If the nursery places orders of 50 bags or less, the cost per bag is $20. For orders greater than 50 bags but less than 100 bags, the cost per bag is $19. For orders of 100 bags or more, the cost is $18 per bag. Greens estimates its holding cost to be 25 percent of the unit price. Determine the most cost-effective ordering policy for Greens.

14. In an effort to reduce its inventory, Rapid Grower is offering Greens, a local nursery (Problems 12 and 13), two additional price breaks to consider. If the nursery orders a three-month supply, the cost per bag is $16. If Greens orders a six-month supply, the cost per bag is $14.50. Should Greens change its order quantity calculated in Problem 13?

15. In a further attempt to liquidate its inventory, Rapid Grower has offered Greens, the local nursery, an option to buy the entire year's supply at one time. The cost per bag would be $12. Should Greens take advantage of this offer?

16. Sam's Auto Shop services and repairs a particular brand of foreign automobile. Sam uses oil filters throughout the year. The shop operates 52 weeks per year, and weekly demand is 150 filters. Sam estimates that it costs $20 to place an order and his annual holding cost rate is $3 per oil filter. Currently, Sam orders in quantities of 650 filters. Calculate the total annual costs associated with Sam's current ordering policy.

17. Using the information in Problem 16, calculate the following:

(a) The economic order quantity
(b) The total annual costs using the EOQ ordering policy
(c) The penalty costs Sam is incurring by using his current policy

18. The local Office of Tourism sells souvenir calendars. Sue, the head of the office, needs to order these calendars in advance of the main tourist season. Based on past seasons, Sue has determined the probability of selling different quantities of the calendars for a particular tourist season.

Demand for Calendars	Probability of Demand
75,000	0.15
80,000	0.25
85,000	0.30
90,000	0.20
95,000	0.10

The Office of Tourism sells the calendars for $12.95 each. The calendars cost Sue $5 each. The salvage value is estimated to be $0.50 per unsold calendar. Determine how many calendars Sue should order to maximize expected profits.

19. The Office of Tourism (Problem 18) has decided to heavily promote local events this year and anticipates more tourists this season. Sue has changed the probability of selling different quantities of calendars as shown. Given the new probabilities, determine how many calendars Sue should order to maximize expected profits.

Demand for Calendars	Probability of Demand
75,000	0.05
80,000	0.20
85,000	0.25
90,000	0.30
95,000	0.20

20. Given the following list of items,
(a) Calculate the annual usage cost of each item.
(b) Classify the items as A, B, or C.

Item	Annual Demand	Ordering Cost ($)	Holding Cost (%)	Unit Price ($)
101	500	10	20	0.50
102	1500	10	30	0.20
103	5000	25	30	1.00
104	250	15	25	4.50
105	1500	35	35	1.20
201	10000	25	15	0.75
202	1000	10	20	1.35
203	1500	20	25	0.20
204	500	40	25	0.80
205	100	10	15	2.50

21. Using the information provided in Problem 20,
(a) Calculate the economic order quantity for each item. (Round to the nearest whole number.)
(b) Calculate the company's maximum inventory investment throughout the year.
(c) Calculate the company's average inventory level.

22. Tax Preparers, Inc. works 250 days per year. The company uses adding machine tape at a rate of eight rolls per day. Usage is believed to be normally distributed with a standard deviation of three rolls during lead time. The cost of ordering the tape is $10, and holding costs are $0.30 per roll per year. Lead time is two days.
(a) Calculate the economic order quantity.
(b) What reorder point will provide an order-cycle service level of 97 percent?
(c) How much safety stock must the company hold to have a 97 percent order-cycle service level?
(d) What reorder point is needed to provide an order-cycle service level of 99 percent?
(e) How much safety stock must the company hold to have a 99 percent order-cycle service level?

23. Healthy Plants Ltd. (HP) produces its premium plant food in 50-pound bags. Demand for the product is 100,000 pounds per week. HP operates 50 weeks per year and can produce 250,000 pounds per week. The setup cost is $200 and the annual holding cost rate is $0.55 per bag. Currently, HP produces its premium plant food in batches of 1,000,000 pounds.
(a) Calculate the maximum inventory level for HP.
(b) Calculate the total annual costs of this operating policy.

24. Using the data provided in Problem 23, determine what will happen if HP uses the economic production quantity model to establish the quantity produced each cycle.
(a) Calculate the economic production quantity (EPQ).
(b) Calculate the maximum inventory level using the EPQ.
(c) Calculate the total annual cost of using the EPQ.
(d) Calculate the penalty cost HP is incurring with its current policy.

25. Greener Pastures Incorporated (GPI) produces a high-quality organic lawn food and weed eliminator called Super Green (SG). Super Green is sold in 50-pound bags. Monthly demand for Super Green is 75,000 pounds. Greener Pastures has capacity to produce 24,000 50-pound bags per year. The setup cost to produce Super Green is $300. Annual holding cost is estimated to be $3 per 50-pound bag. Currently, GP is producing in batches of 2500 bags.
(a) Calculate the total annual costs of the current operating policy at GPI.
(b) Calculate the economic production quantity (EPQ).
(c) Calculate the total annual costs of using the EPQ.
(d) Calculate the penalty cost incurred with the present policy.

26. Lissette Jones, the materials manager for an upscale retailer, wants to measure her customer service level. She has collected the following representative data.

Order Number	Number of Line Items	Dollar Value of Order
1	4	1000
2	8	1440
3	2	1600
4	6	920
5	10	1800
6	8	1200
7	8	2700
8	4	1560
9	5	1780
10	5	1000
Totals	**60**	**$15,000**

Assuming that orders 1–6 and 8–10 shipped on schedule:
(a) Calculate the customer service level using the percentage of orders that shipped on schedule.
(b) Calculate the customer service level using the percentage of line orders that shipped on schedule.
(c) Calculate the customer service level using the percentage of dollar volume that shipped on schedule.
(d) Which of these measures would you recommend to Lissette?

27. Your new company has decided to use a periodic review system. You have learned that average weekly demand is 48 units per week with a standard deviation of 8 units. You believe that your cycle-service level should be 94 percent. Lead time is two weeks. Initially, you believe that you should do a review every Friday. Determine the required safety stock and the target inventory level.
(a) How would this procedure change if the cycle-service level needed to be 98 percent?
(b) What is the impact of changing the review period from every Friday to every other Friday, assuming that the cycle-service level is 94 percent?

28. Michael's Office Supply (MOS) sells office furniture, equipment, and supplies. This week the company has received 50 customer orders. Each order has an average of five line items. The average dollar amount of each order is $1200. MOS was able to ship 47 of the 50 orders on schedule.
(a) Using the percentage of orders shipped on time, calculate the customer service level.
(b) If Michael's calculates customer service level by using the percentage of line items shipped on schedule, how many

line items must be shipped to achieve the same customer service level calculated in part (a)?

(c) If Michael's calculates customer service level by the percentage of dollar volume shipped, how many dollars of product must be shipped to achieve the same customer service level calculated in part (a)?

(d) What factors determine the customer service level measure that MOS should use?

29. My Kitchen Delights (MKD), a regional producer of gourmet jams and jellies, uses approximately 24,000 glass jars each month during its production. Because of space limitations, MKD orders 5000 jars at a time. Monthly holding cost is $0.08 per jar, and the ordering cost is $60 per order. The company operates 20 days per month.

(a) What penalty cost is the company incurring by its present replenishment policy?

(b) MKD would prefer to order eight times each month but needs to justify any change in order size. How much would ordering cost need to be reduced to justify a lot size of 3000 jars?

(c) If MKD can reduce its ordering cost to $30, what is the optimal replenishment order quantity?

30. My Kitchen Delights (MKD) is considering two new suppliers for the jars used in the production process. The quality at both suppliers is equal. Assume that the annual holding cost is 30 percent of the unit price. Monthly demand averages 20,000 jars. Ordering cost with these two suppliers is $30 per order. The price lists for the suppliers are as follows:

Supplier A

Quantity	Unit Price
1–2499	$3.00
2500–3499	2.90
3500–4999	2.80
5000 or more	2.70

Supplier B

Quantity	Unit Price
1–1999	$3.50
2000–2999	3.15
3000–3999	2.85
4000–4999	2.75
5000 or more	2.60

(a) Determine the optimal order quantity when using Supplier A.

(b) Determine the optimal order quantity when using Supplier B.

(c) Given MKD's lack of space, which supplier do you recommend be used? Justify your answer.

CASE: FabQual Ltd.

FabQual Ltd. manufactures parts and subassemblies for a number of small-volume manufacturers of specialized construction equipment, including bulldozers, graders, and cement mixers. FabQual also manufactures and distributes spare parts. The company has made a specialty of providing spare parts for equipment no longer in production; this includes wear parts that are no longer in production for any OEM.

The Materials Management Group (MMG) orders parts—both for delivery to a customer's production line and for spares—from the Fabrication Department. Spares are stocked in a finished goods store. FabQual's part number 650810/ss/R9/o is a wear part made only for spares demand. It has had demand averaging 300 units per week for more than a year, and this level of demand is expected to persist for at least four more years. The standard deviation of weekly demand is 50 units.

The MMG has been ordering 1300 units monthly of part number 650810/ss/R9/o from the Fabrication Department to meet the forecast annual demand of 15,600 units. The order is placed in the first week of each month. In order to provide Fabrication with scheduling flexibility, as well as to help with planning raw material requirements, a three-week manufacturing lead time is allowed for parts.

In the Fabrication Department, two hours is now allowed for each setup for a run of part number 650810/ss/R9/o. This time includes strip-down of the previous setup; delivery of raw materials, drawings, tools and fixtures, and the like; and buildup of the new setup. The two-hour setup time is a recent improvement over the previous four hours, as the result of setup reduction activities in the Fabrication Department. The Fabrication Department charges £20 per hour for setups. (If you prefer to work in dollars, you can find the current exchange rate in the *Wall Street Journal*.) Part number 650810/ss/R9/o enters the finished goods stores at a full manufacturing cost of £55. The Financial Office requires a 25 percent per item per year cost for inventory planning and control. (This is your annual holding cost rate.)

Case Questions

1. What is the total annual cost of the present ordering policy for part number 650810/ss/R9/o?
2. What would be the lot size for part number 650810/ss/R9/o if FabQual were to use an economic order quantity (EOQ)?
3. What would be the total annual cost of using an economic order quantity for part number 650810/ss/R9/o?
4. What would be the reorder point for part number 650810/ss/R9/o if FabQual wanted a delivery performance of 95 percent? What would it be if the company wanted a delivery performance of 99 percent?
5. Under the present scheme—ordering 1300 units each month in the first week of each month—there are typically 700 to 800 units on hand when the new batch of 1300 units arrives toward the end of each month. What would be the impact on the overall inventory level of part number 650810/ss/R9/o of a change from the present order policy to an EOQ-based policy?
6. What are other implications of a change from the present scheme to one based on the economic order quantity? If this part is representative of a great many spare parts, what would be the overall impact?

CASE: Kayaks!Incorporated

Kayaks!Incorporated manufactures a line of sea kayaks and accessories in a make-to-stock environment. These products are sold to boat dealers and major department stores throughout North America, which then sell these products to the final customer. Customers expect immediate receipt of the goods, so it is critical to have sufficient inventory held by the dealers and department stores. Aeesha Grant, the materials manager at Kayaks! wants to make sure that the customer service level is being correctly calculated before she considers any changes to manufacturing. She has collected the following information for you to analyze and prepare a report on the customer service level being provided by Kayaks!Incorporated to the boat dealers and department stores.

Case Questions

1. Kayaks!Incorporated has always measured customer service as the number of complete orders that ship on schedule. Using this measure, calculate the customer service level provided by Kayaks!Incorporated.
2. Does this method of calculating the customer service level make sense for Kayaks!Incorporated?
3. What other methods might be useful in measuring Kayaks! customer service level? How would these affect your analysis of customer service?
4. What is your report to Aeesha Grant with regard to the customer service being provided by Kayaks!Incorporated?

Customer	Line Items	Dollar Value	Line Items Shipped on Schedule	Dollar Value on Schedule
1	2	2,000	2	2,000
2	17	40,000	16	37,500
3	9	16,000	9	16,000
4	7	9,500	6	9,000
5	24	68,000	22	64,000
6	4	6,000	4	6,000
7	7	14,000	7	14,000
8	3	14,000	3	14,000
9	9	6,000	7	4,800
10	12	18,500	11	18,000
11	7	16,000	7	16,000
12	12	14,000	11	11,000
13	11	19,500	9	15,000
14	5	8,000	5	8,000
15	5	6,000	5	6,000
16	7	12,000	6	11,500
17	16	28,000	15	24,500
18	11	12,000	11	12,000
19	9	17,500	9	17,500
20	3	7,500	3	7,500
21	4	11,000	4	11,000
22	8	12,000	8	12,000
23	20	48,000	19	44,000
24	1	2,500	1	2,500
25	12	9,000	12	9,000
Totals	**225**	**417,000**	**212**	**392,800**

INTERACTIVE CASE Virtual Company

www.wiley.com/college/reid

On-line Case: Cruise International, Inc.

Assignment: *Innventory Management at Cruise International, Inc.* In this assignment you will work with Andrew Jaworski, the cruise ship's Medical Officer. He has a special offer from a supplier for a disposable syringe filled with a premeasured dosage of medicine to alleviate motion sickness, which needs to be evaluated. He has provided you with all the necessary information needed to analyze the quantity discount offered by the supplier. One additional concern comes from Peggy Johnson, the Corporate Medical Officer. The Food and Drug Administration (FDA) is currently testing a new motion sickness medicine that would make the other medicine obsolete. She believes there is a 10 percent chance of the new medicine receiving FDA approval and that we will know in approximately nine months. Your job is to make a recommendation regarding this quantity discount offer. This assignment will enable you to enhance your knowledge of the material in Chapter 12 of your textbook and prepare you for future assignments.

To access the Web site:

- Go to **www.wiley.com/college/reid**
- Click **Student Companion Site**
- Click **Virtual Company**
- Click **Consulting Assignments**
- Click **Inventory Management at CII**

INTERNET CHALLENGE Community Fund-Raiser (A)

Your nonprofit club holds a major fund-raiser for two weeks each year to support community improvement projects. The club sells packages of cookies throughout the community and donates the proceeds. The goal of the event is to raise at least $40,000 for the community. This year you are in charge of the fund-raising event. Your first step is to search the Internet and identify at least three potential suppliers of the cookies to be sold this year. At least one of the suppliers should be in the immediate vicinity of your town or city.

From past fund-raisers, the club believes that an acceptable price of the cookies to the customers does not allow for more than a $1 markup over the regular cost per package. However, if quantity discounts can be obtained, then the profit per package can exceed $1. It is believed that regardless of the cookies sold, demand will be 40,000 packages. If you decide to buy more than 40,000 packages, any leftover cookies will be donated to local shelters. Since you are a nonprofit organization, no tax advantage is gained.

For each of the potential suppliers, you need to identify the total cost associated with buying the packages of cookies. Be sure to consider transportation costs as well as any quantity discounts. Remember that your objective is to raise at least $40,000 for the community. It is also important to consider the logistics of your plan. Will all of the cookies arrive at one time or will deliveries be spread over the two-week fund-raiser? Find out how far in advance you need to place your order and when payment for the cookies is due. Explain how you can be sure the cookies will arrive on time. You need to put together a report for your next meeting comparing your three suppliers and make a recommendation as to which supplier should be used, the quantity of cookies to purchase, the expected profit to be donated, and the logistics for the fund-raiser.

On-line Resources

Companion Website www.wiley.com/college/reid:

- Take interactive *practice quizzes* to assess your knowledge and help you study in a dynamic way
- Review *PowerPoint slides* or print slides for notetaking
- Download *Excel Templates* to use for problem solving
- Access the *Virtual Company: Cruise International, Inc.*
- Find links to *Company Tours* for this chapter
  - **Coffman Stairs—Division of Visador Company**
  - **Canadian Springs Water Company**
- Find links for *Additional Web Resources* for this chapter
  - **Coffman Stairs, *www.coffmanstairs.com/about.htm***
  - **Folbot, *www.folbot.com/plant.tour.html***
  - **Universal Screenprinting, *www.simon.ca/simonfr.htm***

Additional Resources Available Only in WileyPLUS:

- Use the *e-Book* and launch directly to all interactive resources
- Take the interactive *Quick Test* to check your understanding of the chapter material and get immediate feedback on your responses
- Check your understanding of the key vocabulary in the chapter with *Interactive Flash Cards*
- Use the *Animated Demo Problems* to review key problem types
- Practice for your tests with *additional problem sets*
- *And more!*

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